US009256140B2

(12) **United States Patent**
Kanaya

(10) **Patent No.: US 9,256,140 B2**
(45) **Date of Patent: Feb. 9, 2016**

(54) **MOVABLE BODY APPARATUS, PATTERN FORMATION APPARATUS AND EXPOSURE APPARATUS, AND DEVICE MANUFACTURING METHOD WITH MEASUREMENT DEVICE TO MEASURE MOVABLE BODY IN Z DIRECTION**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 951 days.

(21) Appl. No.: **12/263,659**

(22) Filed: **Nov. 3, 2008**

(65) **Prior Publication Data**

US 2009/0115982 A1 May 7, 2009

Related U.S. Application Data

(60) Provisional application No. 60/996,248, filed on Nov. 7, 2007.

(51) **Int. Cl.**
G03F 7/20 (2006.01)
G03F 9/00 (2006.01)

(52) **U.S. Cl.**
CPC ***G03F 7/70775*** (2013.01); ***G03F 9/7034*** (2013.01)

(58) **Field of Classification Search**
CPC G03F 7/70775
USPC 355/72, 73–76, 53; 356/616
See application file for complete search history.

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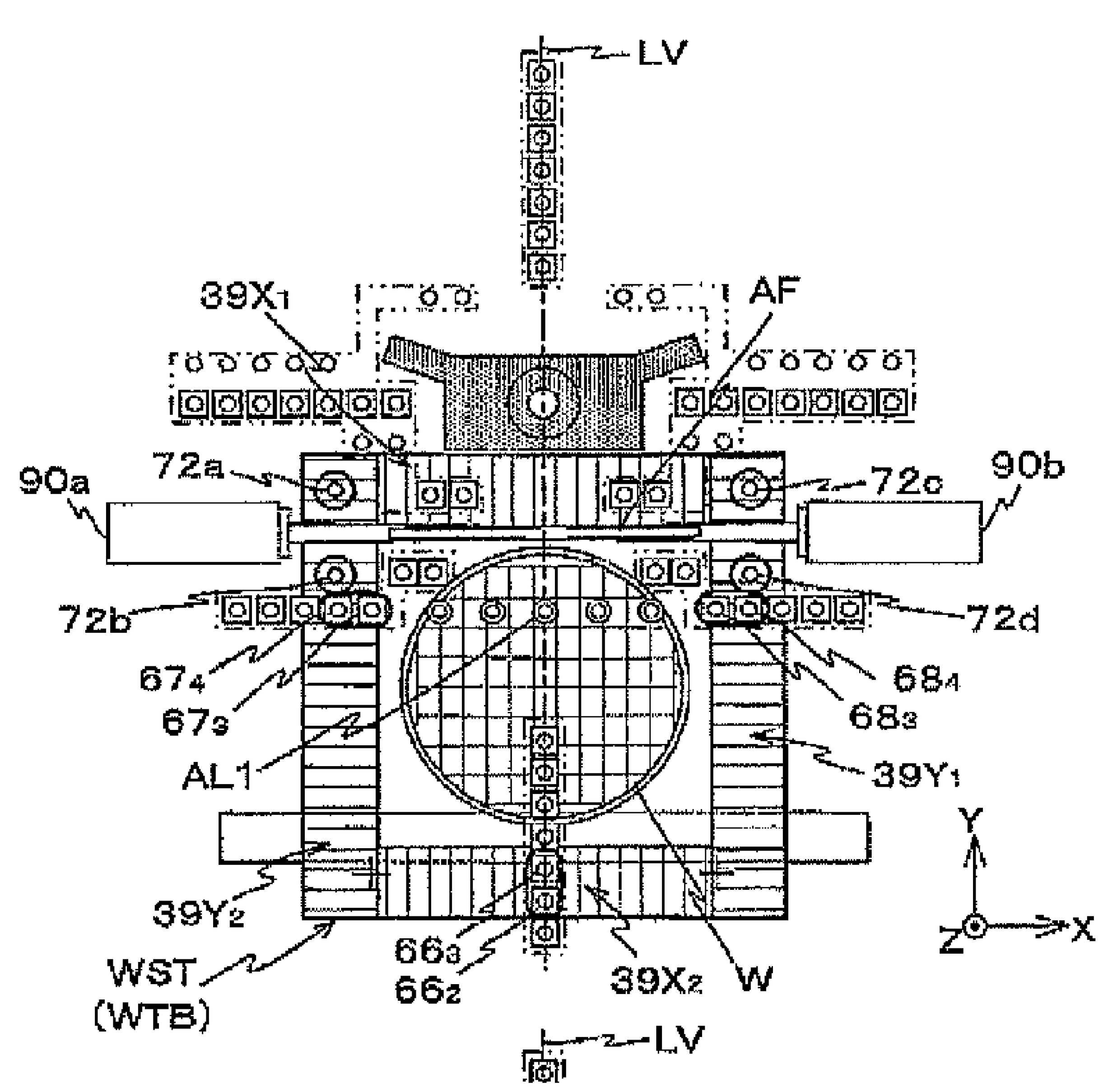
(57) **ABSTRACT**

On the +X and −X sides of a projection unit, a plurality of Z heads are arranged in parallel to the X-axis, by a predetermined distance half or less than half the effective width of the Y scale so that two Z heads each constantly form a pair and face a pair of Y scales. Of the pair of heads consisting of two Z heads which simultaneously face the scale, measurement values of a priority head is used, and when abnormality occurs in the measurement values of the priority head due to malfunction of the head, measurement values of the other head is used, and the positional information of the stage in at least the Z-axis direction can be measured in a stable manner and with high precision.

32 Claims, 12 Drawing Sheets



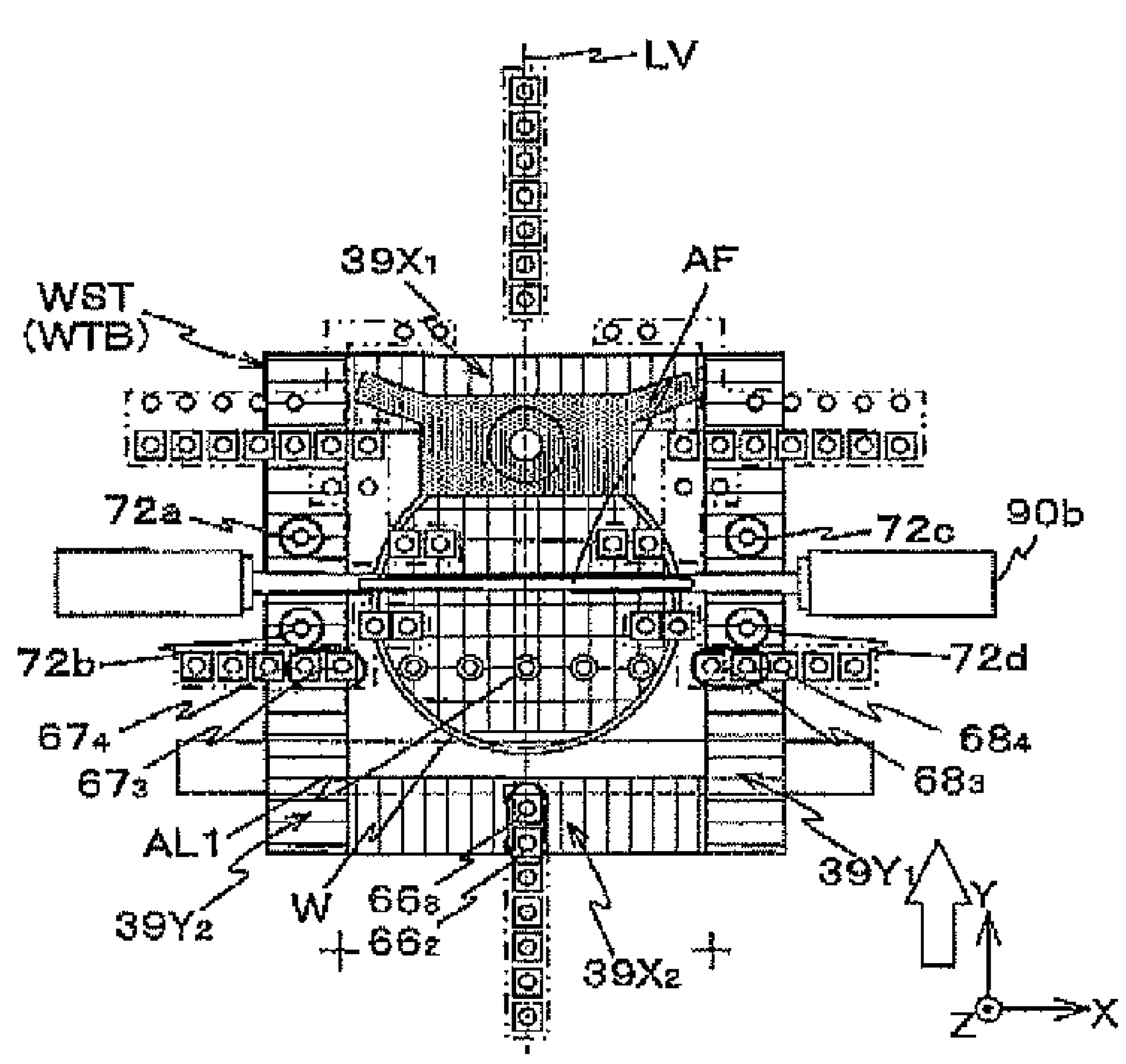


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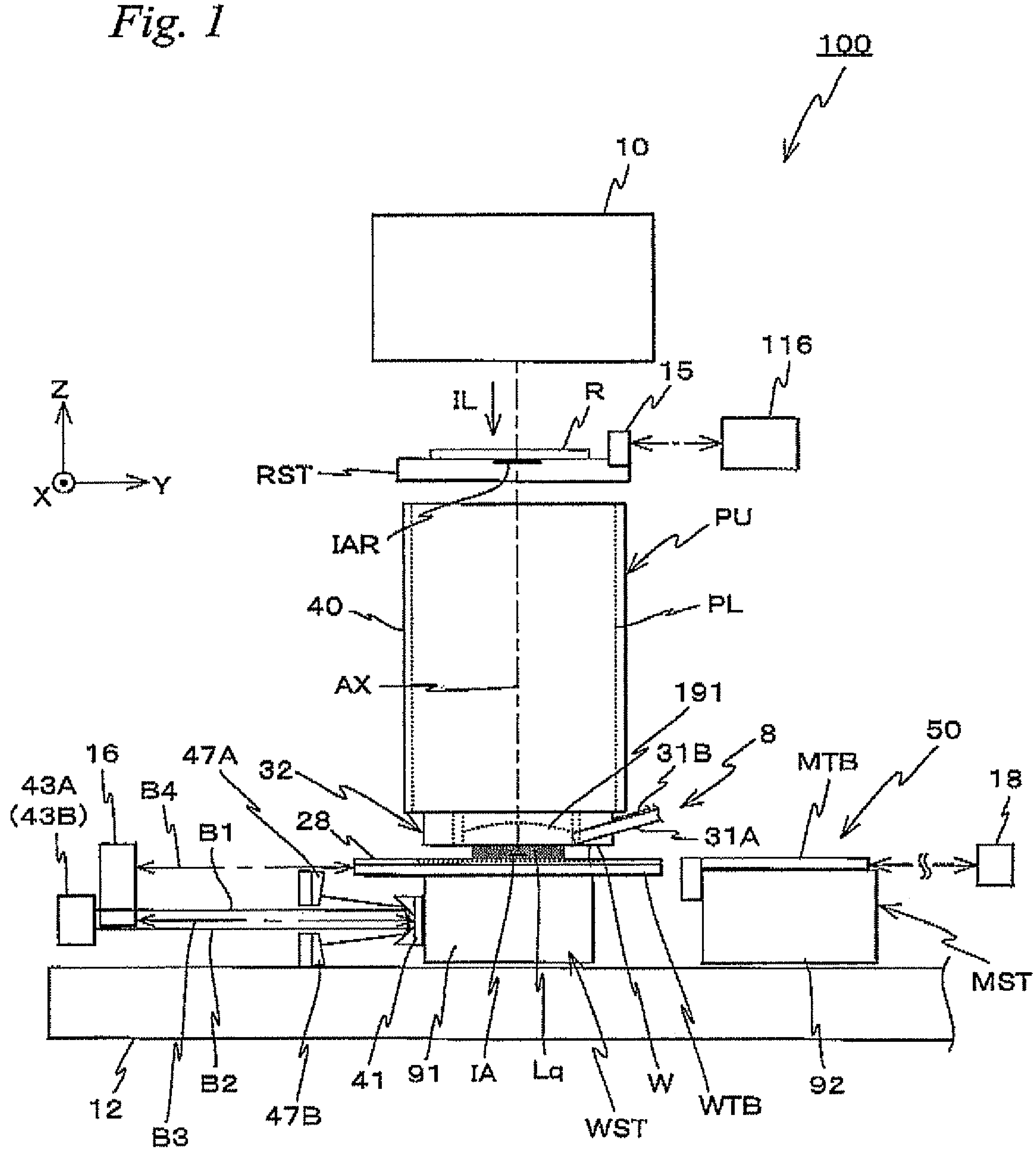
Fig. 1



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Y
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PU
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PL
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191
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31B
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16
47A
32
MTB
18
43A
(43B)
B4
B1
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31A
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12
B2
47B
41
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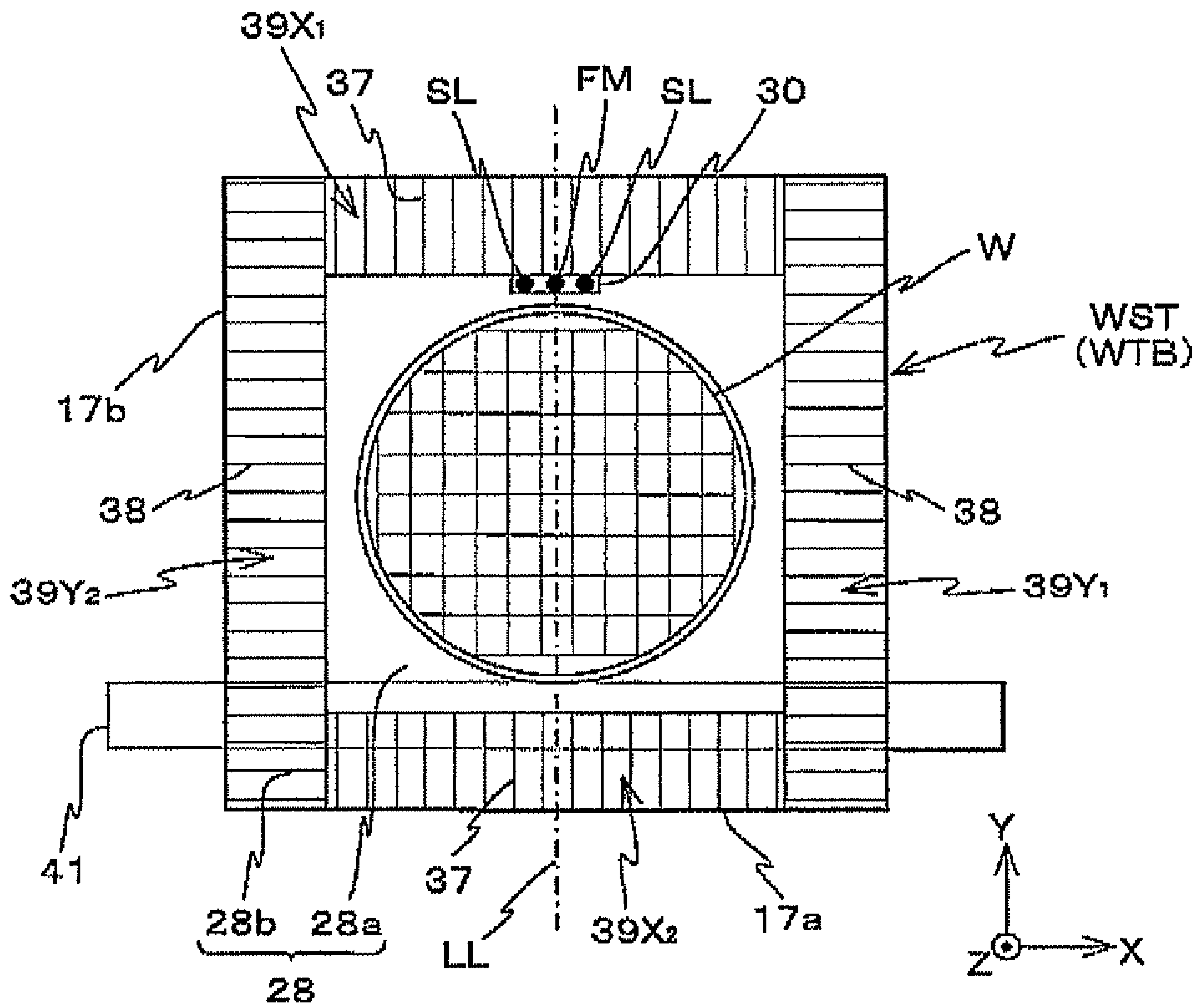
Lq
W
WTB
92
B3
WST

Fig. 2A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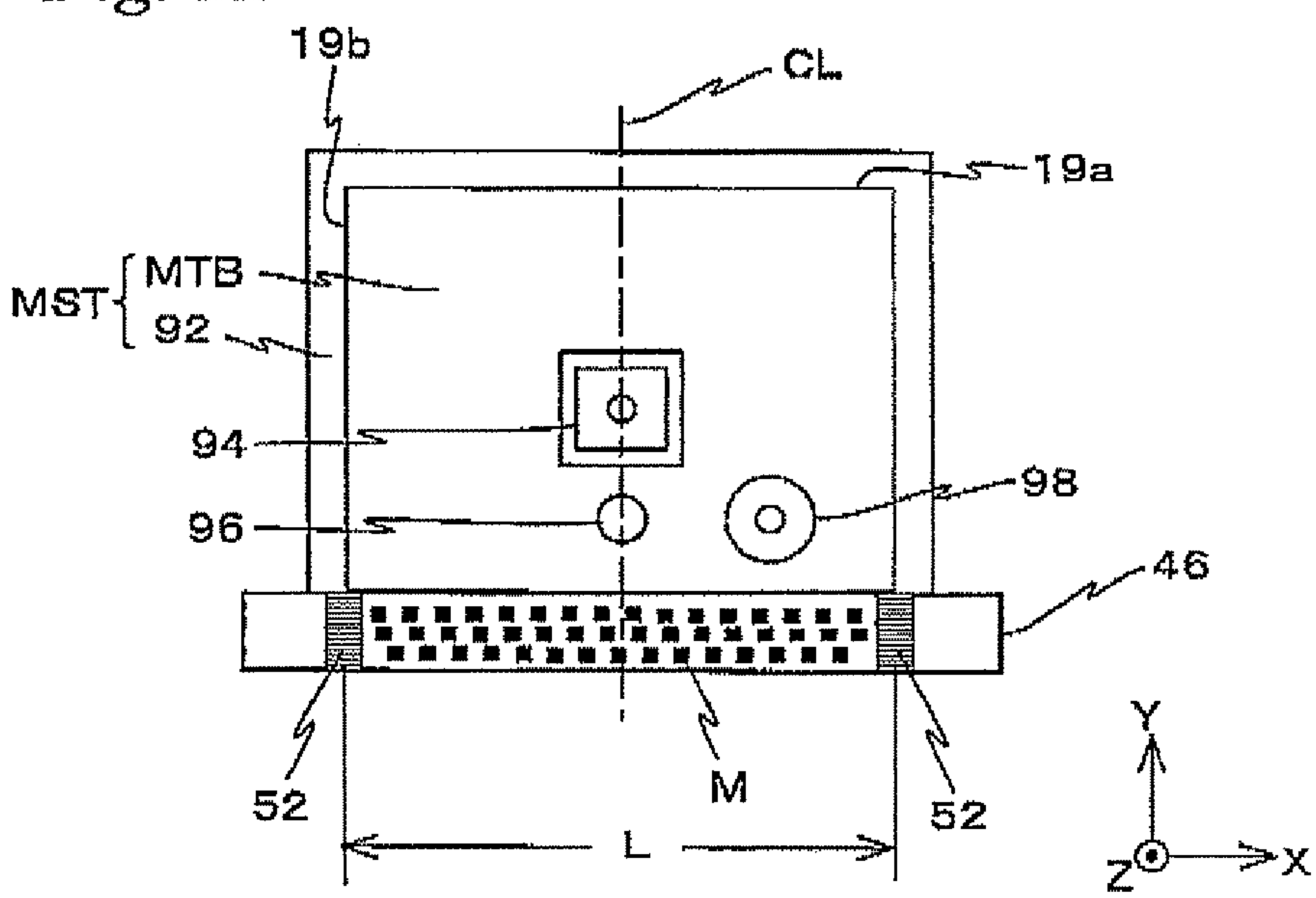
37
LL
39X2
17a
Y
Z
X

Fig. 2B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Z
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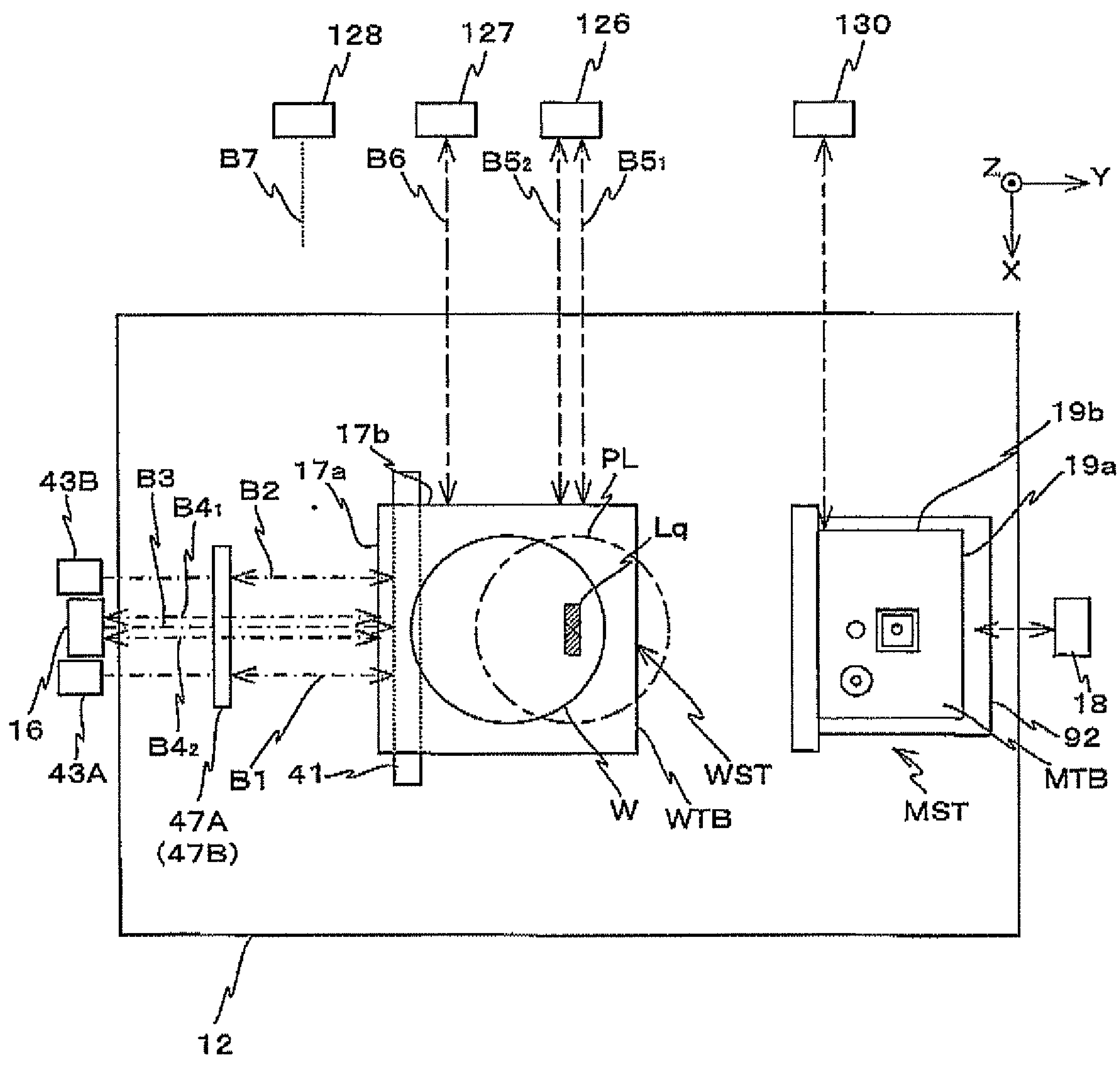
Fig. 3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B6
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B5₁
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PL
19b
19a
43B
B3
B4₁
B2
Lq
16
43A
B4₂
B1
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(47B)
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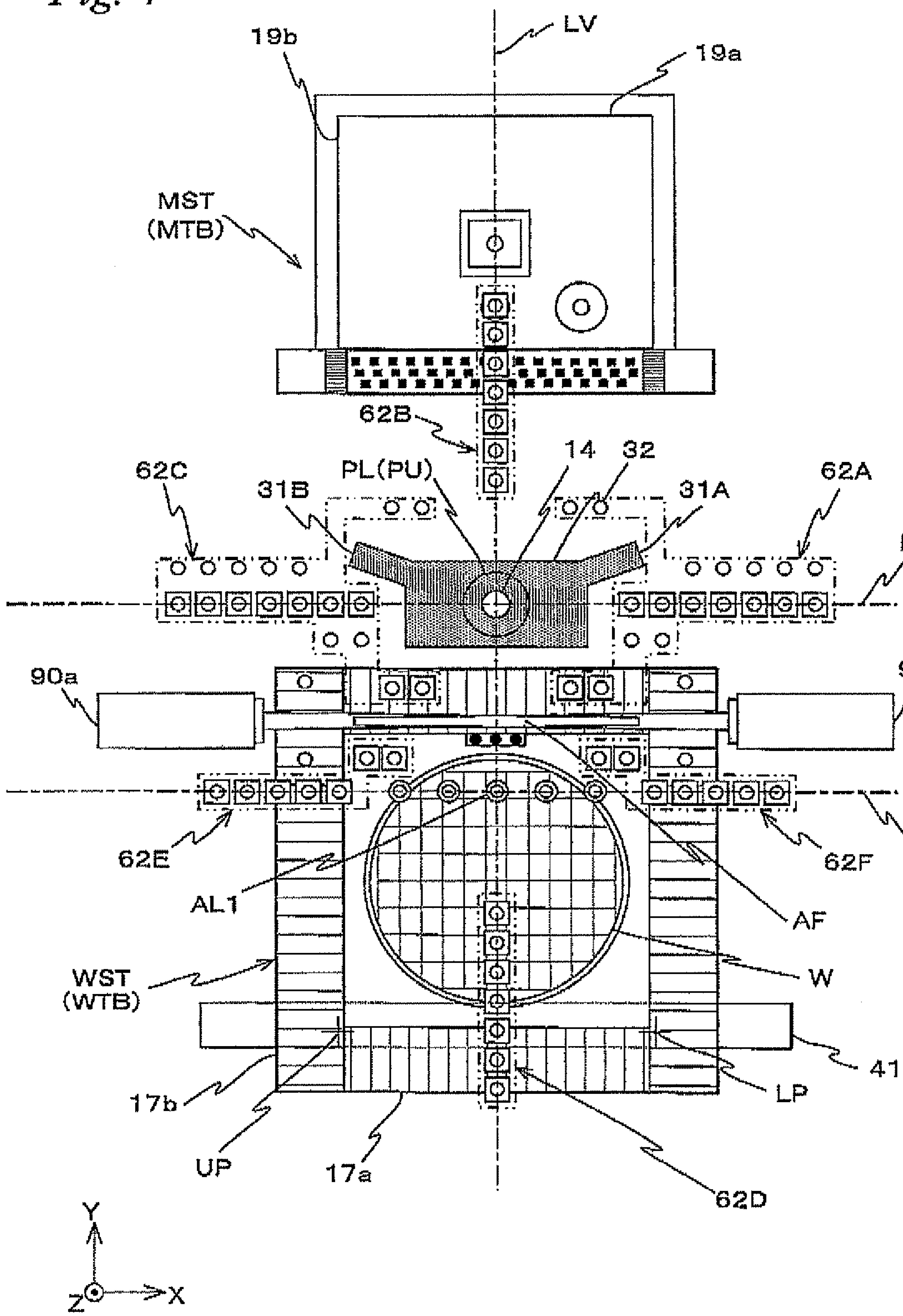
WST
MST
18
92
MTB
12

Fig. 4



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19b
19a
MST
(MTB)
62B
14
32
62C
PL(PU)
62A
31B
31A
LH
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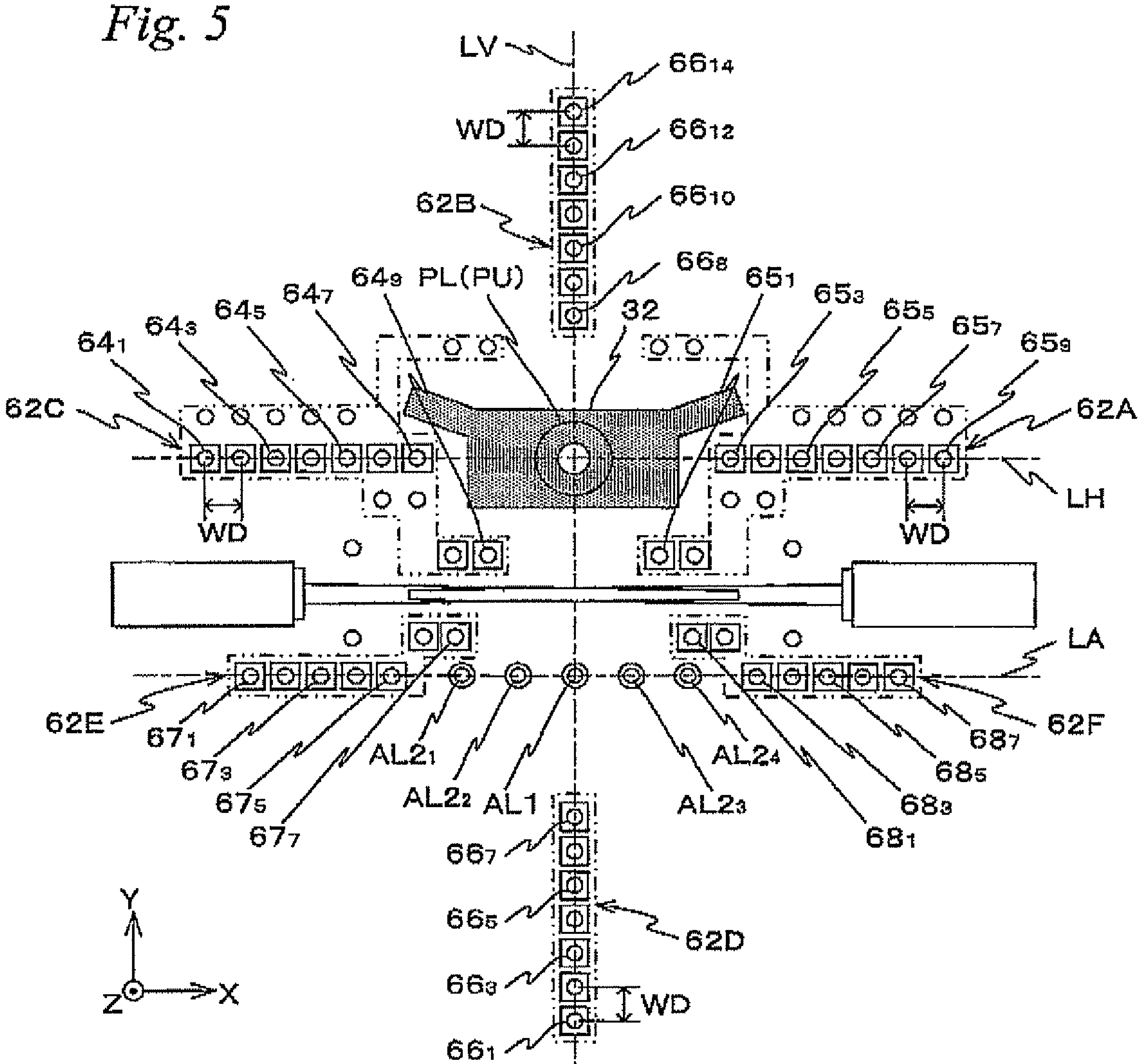
90b
62E
62F
LA
AL1
AF
W
WST
(WTB)
41
17b
LP
UP
17a
62D
Y
Z
X

Fig. 5



LV
66₁₄
WD
66₁₂
62B
66₁₀
66₈
64₉ PL(PU)
32
65₁
65₃
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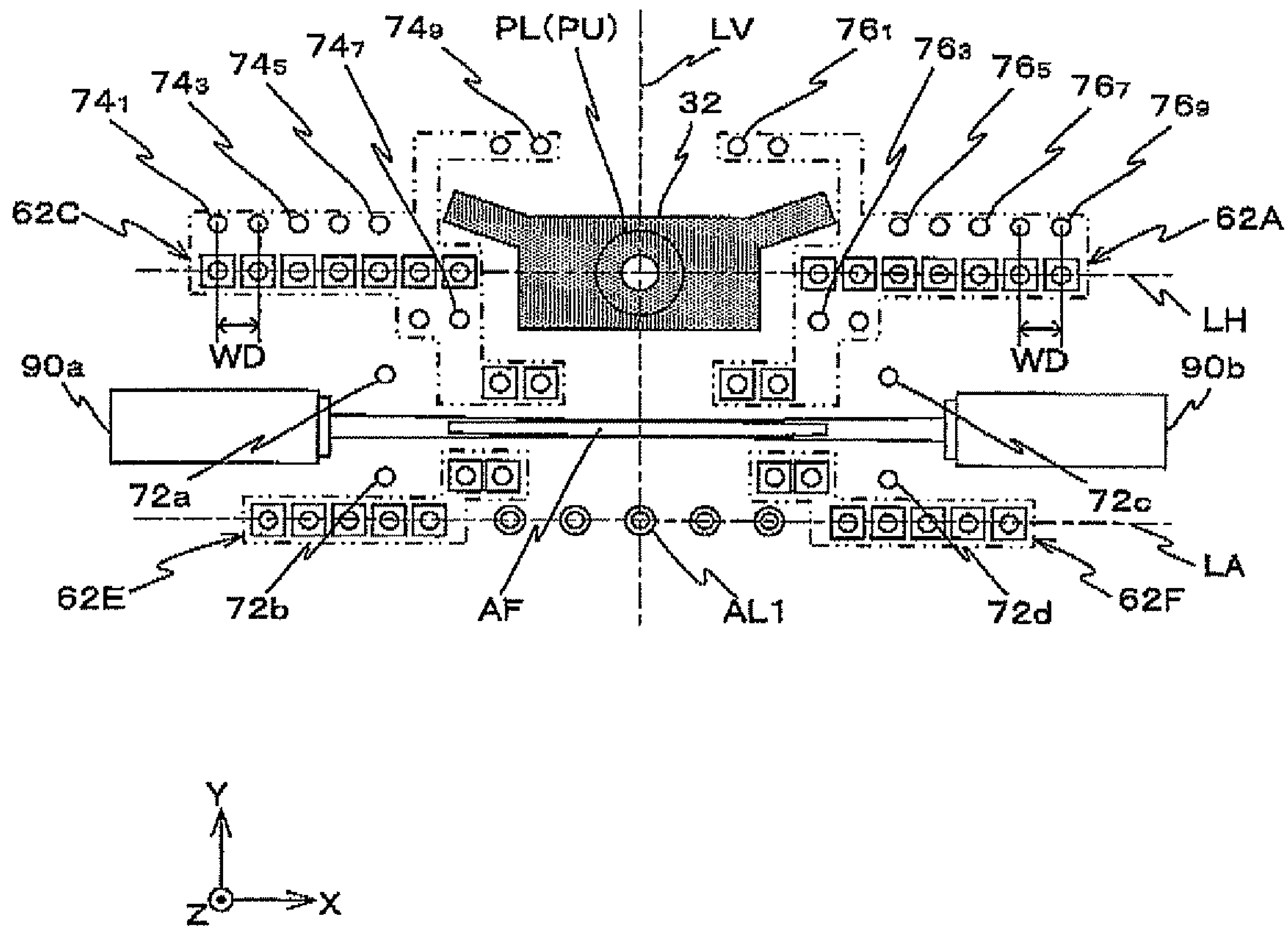
65₇
65₉
64₁
64₃
64₅
64₇
62C
62A
LH
WD
WD
LA
62E
67₁
67₃
67₅
67₇
AL2₁
AL2₂
AL1
AL2₃
AL2₄
68₁
68₃
68₅
68₇
62F
66₇
66₅
62D
66₃
WD
66₁
Y
Z
X

Fig. 6



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74_5
74_7
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76_7
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62A
LH
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90a
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72a
72c
LA
62E
72b
AF
AL1
72d
62F
Y
Z
X

Fig. 7

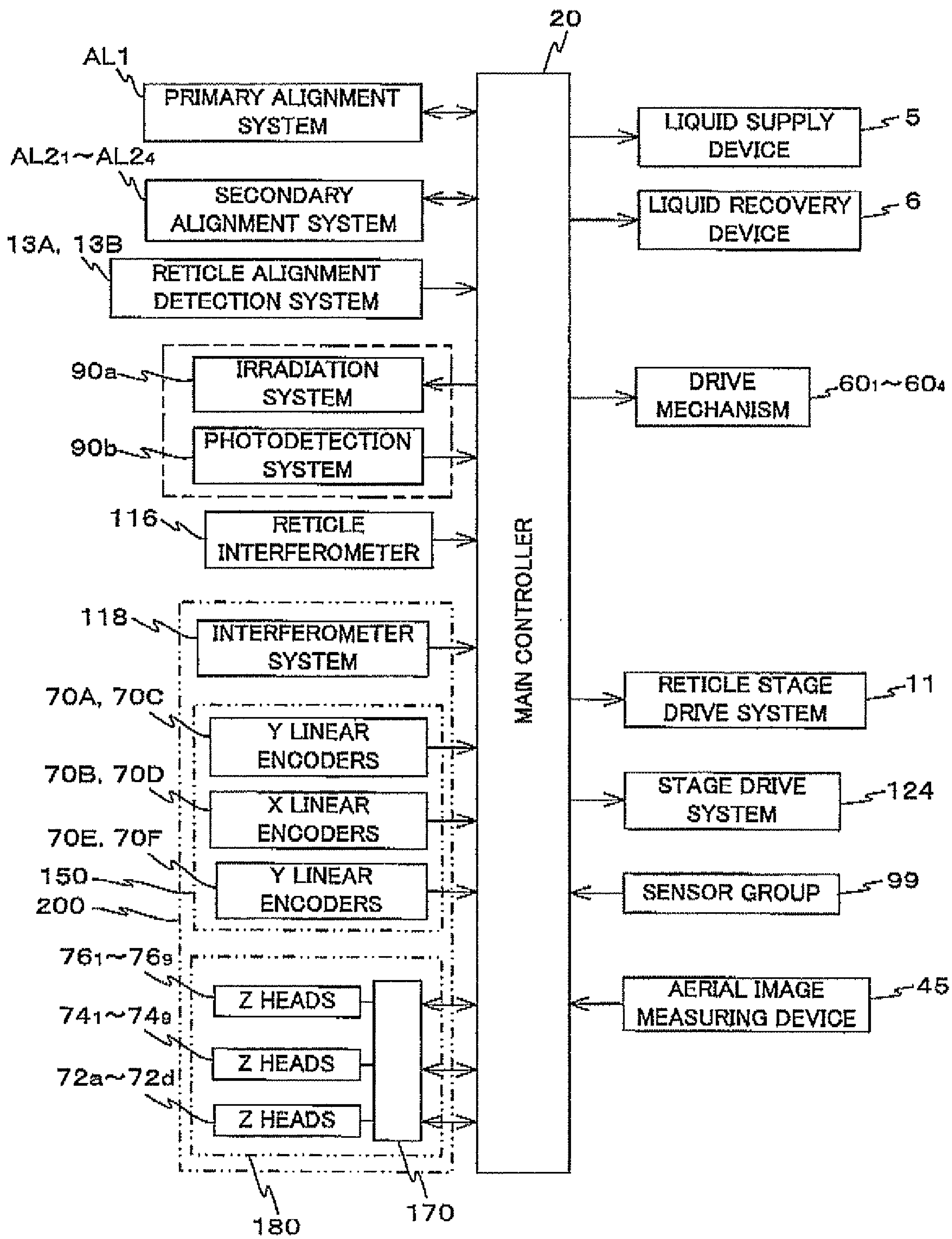
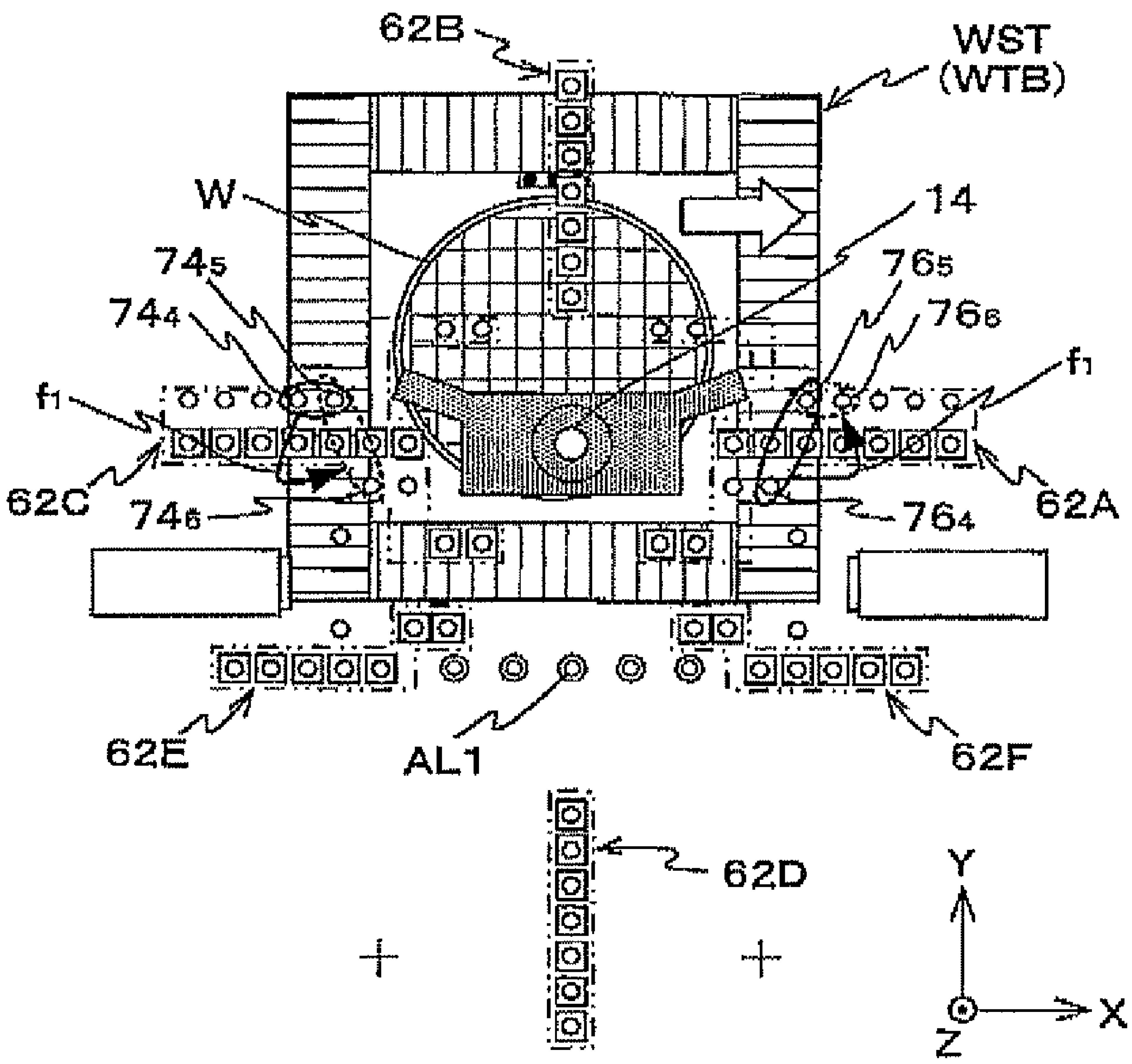

20
AL1
PRIMARY ALIGNMENT SYSTEM
AL2₁~AL2₄
SECONDARY ALIGNMENT SYSTEM
13A, 13B
RETICLE ALIGNMENT DETECTION SYSTEM
90a
IRRADIATION SYSTEM
90b
PHOTODETECTION SYSTEM
116
RETICLE INTERFEROMETER
118
INTERFEROMETER SYSTEM
70A, 70C
Y LINEAR ENCODERS
70B, 70D
X LINEAR ENCODERS
70E, 70F
150
200
Y LINEAR ENCODERS
76₁~76₉
Z HEADS
74₁~74₉
Z HEADS
72a~72d
Z HEADS
180
170
MAIN CONTROLLER
LIQUID SUPPLY DEVICE
5
LIQUID RECOVERY DEVICE
6
DRIVE MECHANISM
60₁~60₄
RETICLE STAGE DRIVE SYSTEM
11
STAGE DRIVE SYSTEM
124
SENSOR GROUP
99
AERIAL IMAGE MEASURING DEVICE
45

Fig. 8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AL1
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Y
X
Z

Fig. 9A

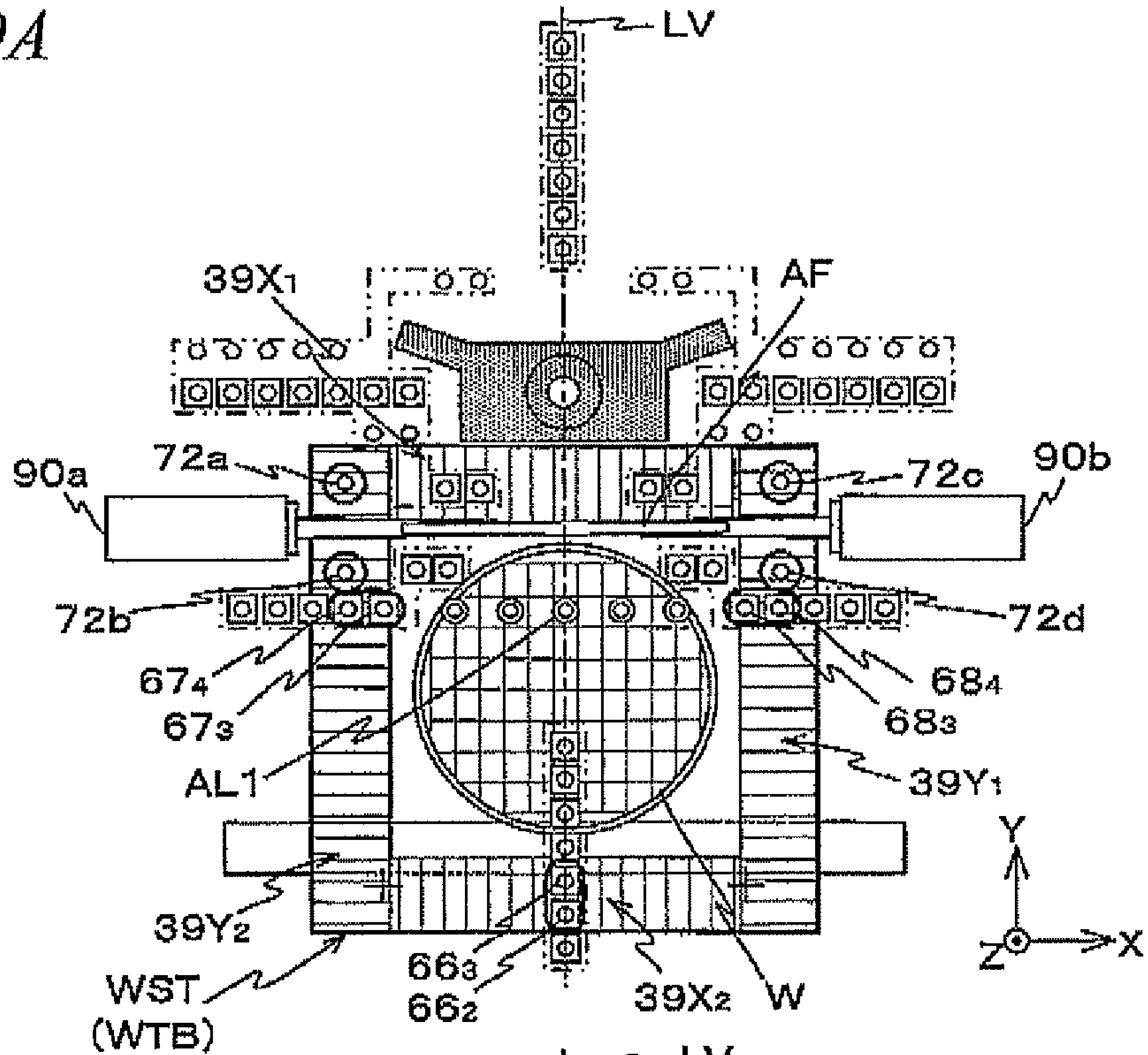


Fig. 9B

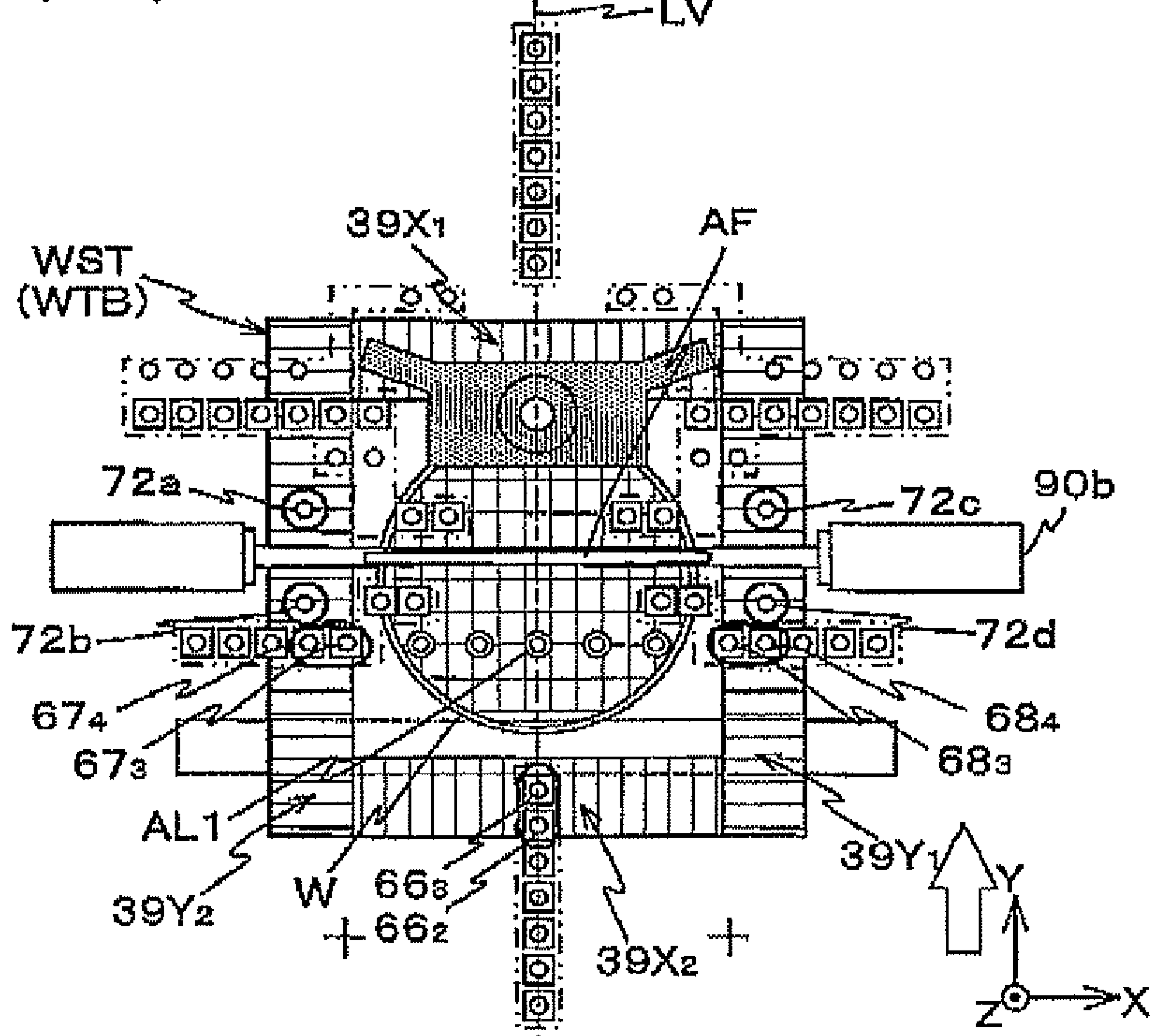


Fig. 9C

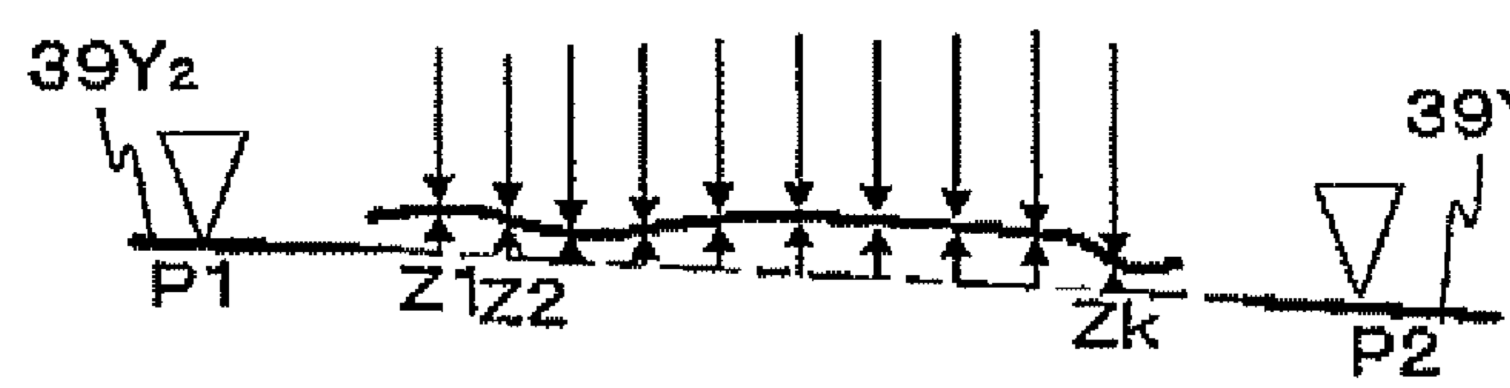
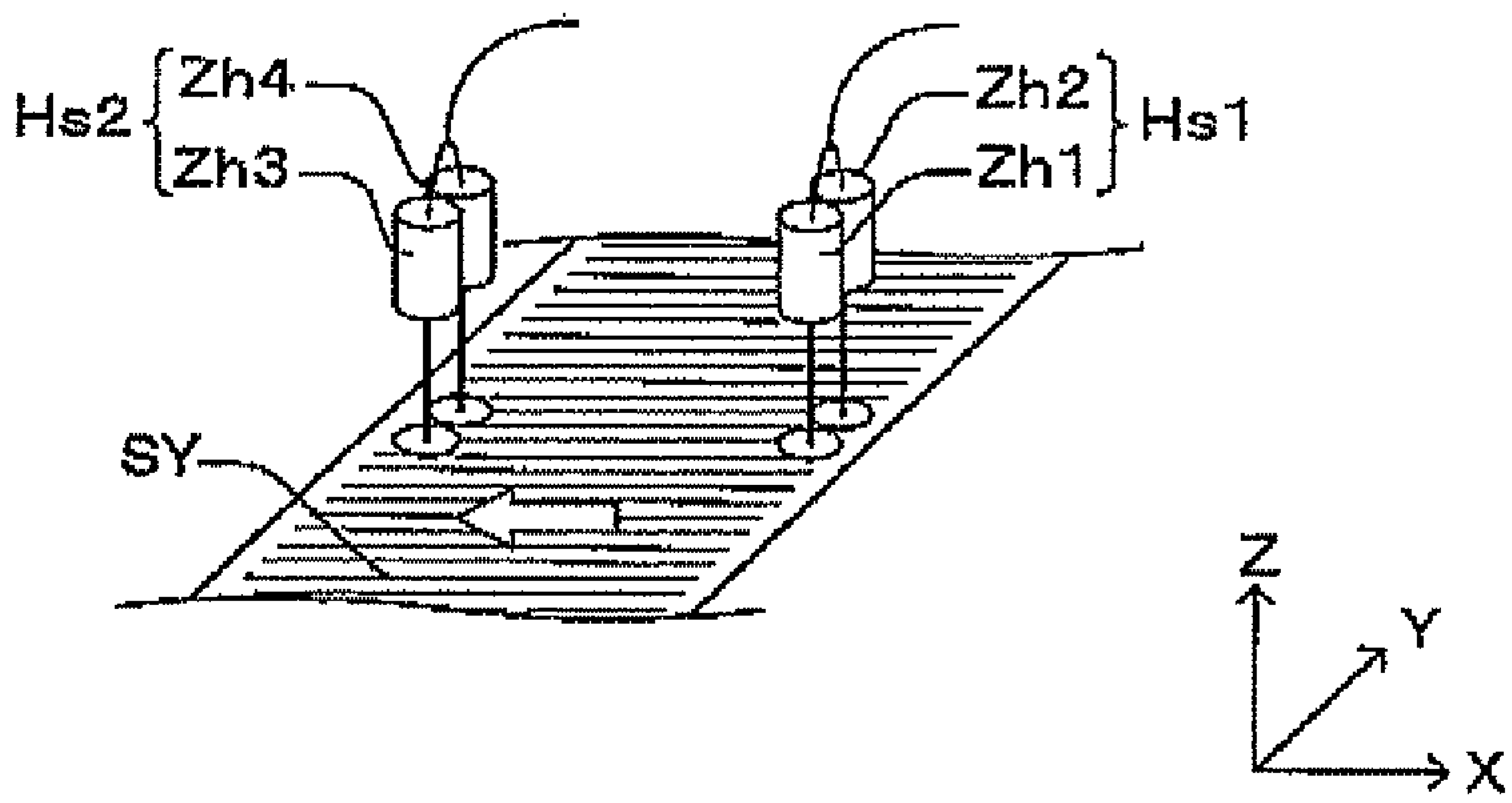


Fig. 10A



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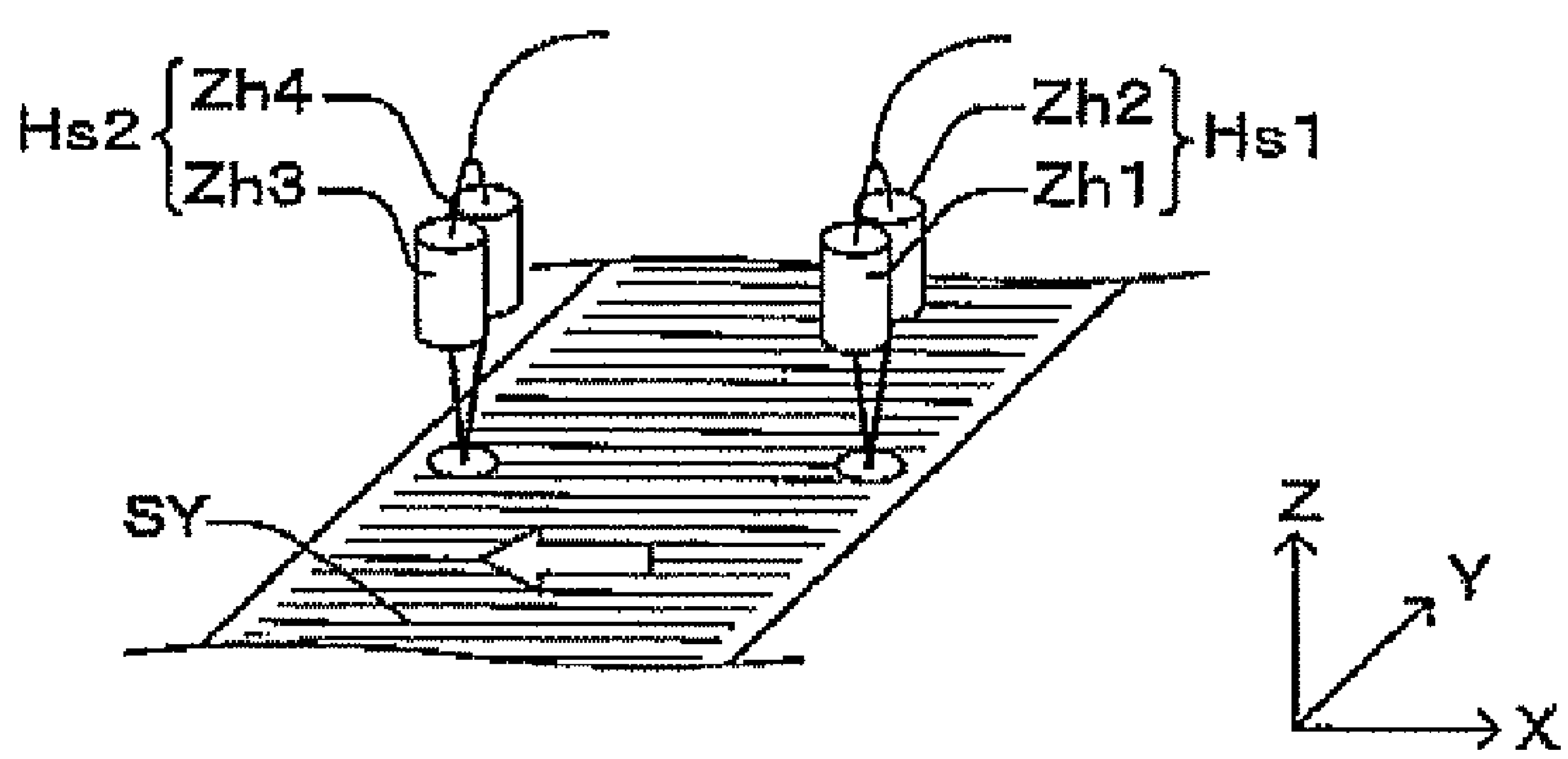


Fig. 11A

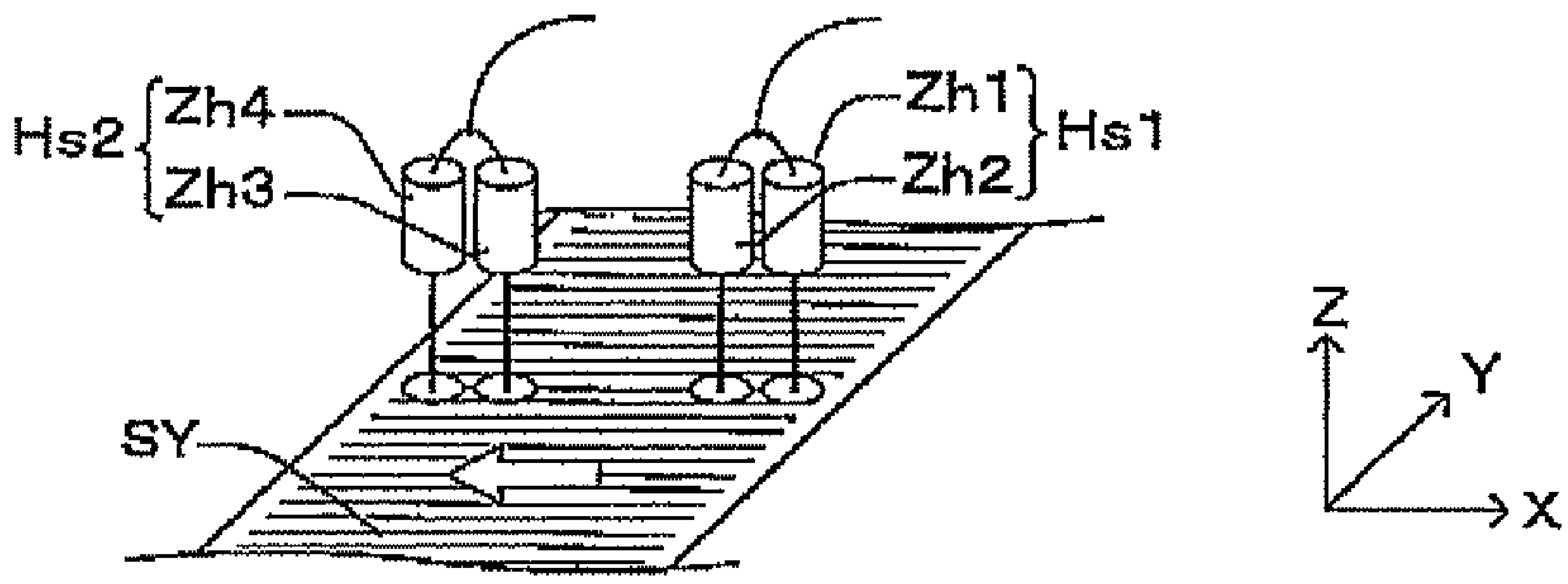


Fig. 11B

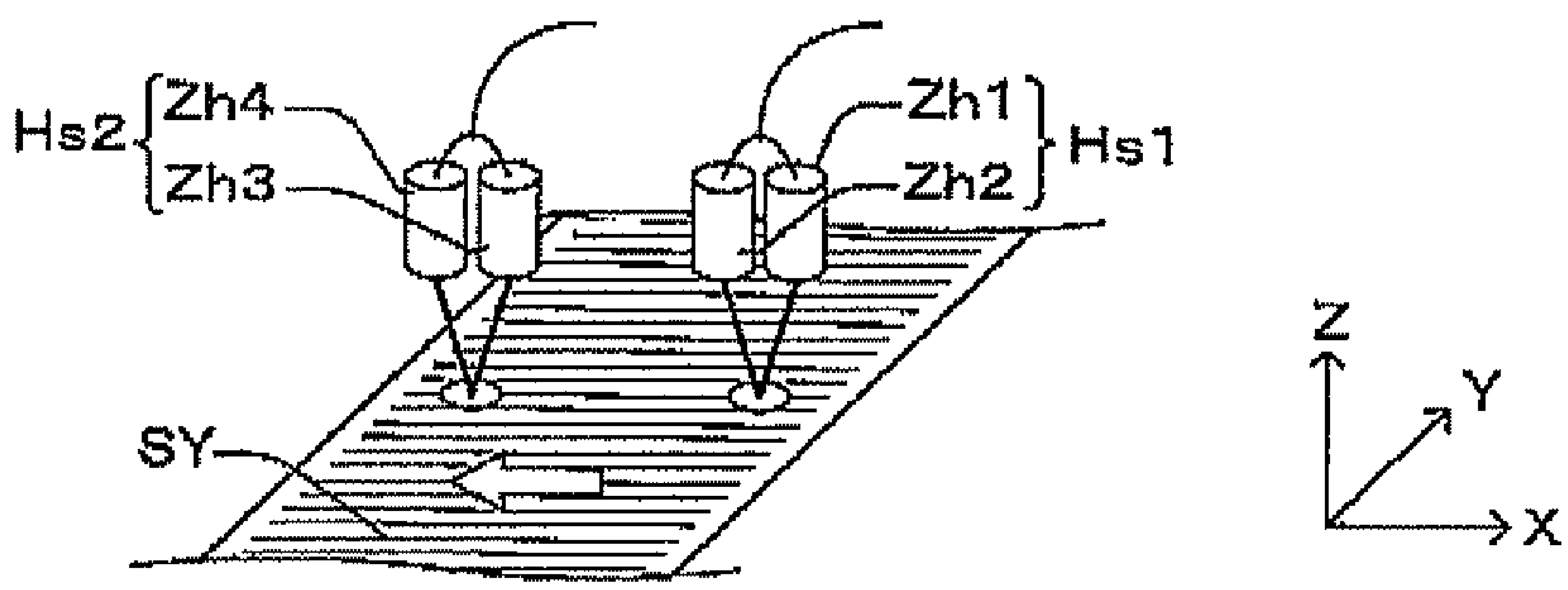
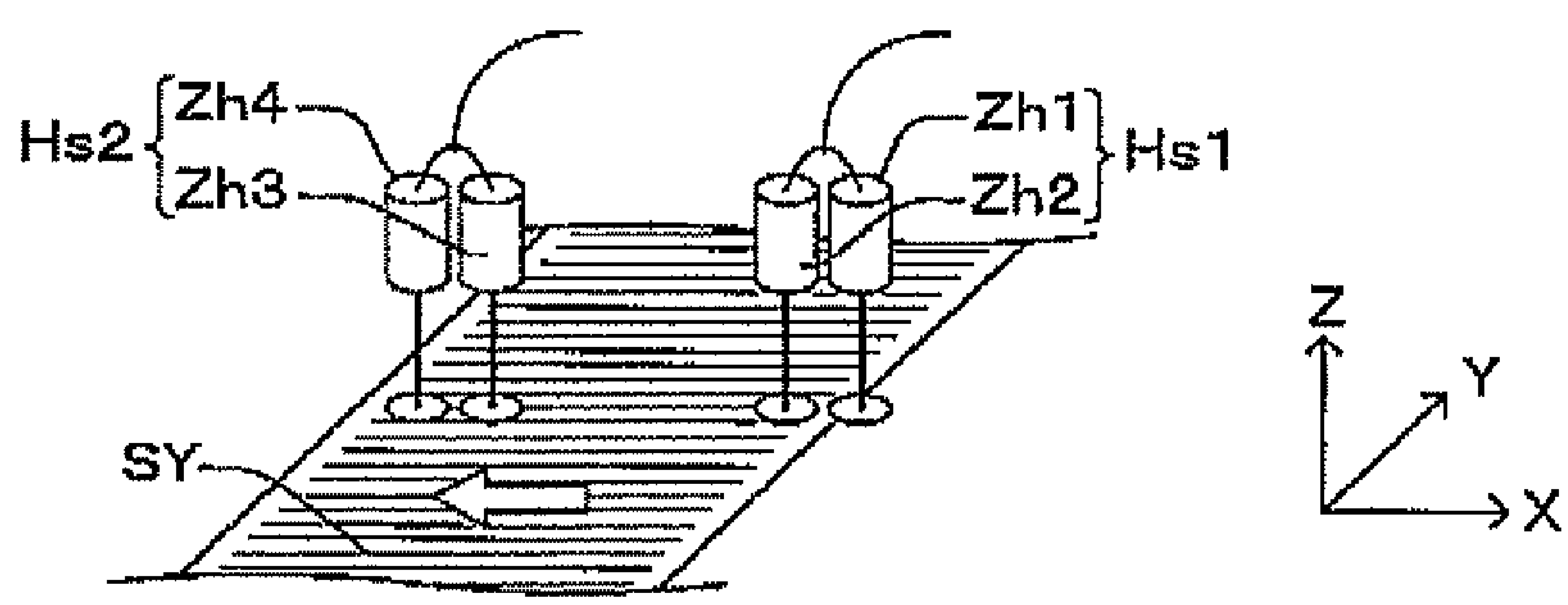


Fig. 12



MOVABLE BODY APPARATUS, PATTERN FORMATION APPARATUS AND EXPOSURE APPARATUS, AND DEVICE MANUFACTURING METHOD WITH MEASUREMENT DEVICE TO MEASURE MOVABLE BODY IN Z DIRECTION

CROSS-REFERENCE TO RELATED APPLICATIONS

This non-provisional application claims the benefit of Provisional Application No. 60/996,248 filed Nov. 7, 2007, the disclosure of which is hereby incorporated herein by reference in its entirety.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to movable body apparatus, pattern formation apparatus and exposure apparatus, and device manufacturing methods, and more particularly, to a movable body apparatus equipped with a movable body which substantially moves along a predetermined plane, a pattern formation apparatus which forms a pattern on an object mounted on a movable body, an exposure apparatus which forms a pattern on an object by irradiating an energy beam, and a device manufacturing method which uses the exposure apparatus.

2. Description of the Background Art

Conventionally, in a lithography process for manufacturing electron devices (microdevices) such as semiconductor devices (such as integrated circuits) and liquid crystal display devices, exposure apparatuses such as a projection exposure apparatus by a step-and-repeat method (a so-called stepper) and a projection exposure apparatus by a step-and-scan method (a so-called scanning stepper (which is also called a scanner) are mainly used.

However, the surface of a substrate subject to exposure such as a wafer, a glass plate or the like (hereinafter generally referred to as a wafer) is not always flat, for example, by undulation and the like of the wafer. Therefore, especially in a scanning exposure apparatus such as a scanner and the like, when a reticle pattern is transferred onto a shot area on a wafer by a scanning exposure method, positional information (focus information) related to an optical axis direction of a projection optical system of the wafer surface is detected at a plurality of detection points set in an exposure area, for example, using a multiple point focal point position detection system (hereinafter also referred to as a "multipoint AF system") and the like, and based on the detection results, a so-called focus leveling control is performed (for example, U.S. Pat. No. 5,448,332) to control the position in the optical axis direction and the inclination of a table or a stage holding a wafer so that the wafer surface constantly coincides with an image plane of the projection optical system in the exposure area (the wafer surface is within the focal depth of the image plane).

Further, with the stepper or the scanner and the like, wavelength of exposure light used with finer integrated circuits is becoming shorter year by year, and numerical aperture of the projection optical system is also gradually increasing (higher NA), which improves the resolution. Meanwhile, due to shorter wavelength of the exposure light and higher NA in the projection optical system, the depth of focus had become extremely small, which caused a risk of focus margin shortage during the exposure operation. Therefore, as a method of substantially shortening the exposure wavelength while substantially increasing (widening) the depth of focus when compared with the depth of focus in the air, the exposure apparatus that uses the immersion method has recently begun to gather attention (refer to, U.S. patent Application Publication No. 2005/0259234).

However, in the exposure apparatus using this liquid immersion method or other exposure apparatus whose distance (working distance) between the lower end surface of the projection optical system and the wafer is small, it is difficult to place the multipoint AF system in the vicinity of the projection optical system. Meanwhile, in the exposure apparatus, in order to realize exposure with high precision, performing the focus leveling control described above with high precision in a stable manner is required.

SUMMARY OF THE INVENTION

According to a first aspect of the present invention, there is provided a first movable body apparatus including a movable body which substantially moves along a predetermined plane, the apparatus comprising: a reflection surface which is arranged at one of the movable body and the outside of the movable body, with a first direction within a plane parallel to the predetermined plane serving as a longitudinal direction, and having a predetermined width in a second direction orthogonal to the first direction; and a measurement device which measures positional information of the movable body in a third direction orthogonal to the predetermined plane at a plurality of measurement points placed on the reflection surface, whereby the placement of the plurality of measurement points is decided so that of the plurality of measurement points, n points (wherein, n is an integer of two or more) or more are positioned within the predetermined width on the reflection surface, and when the movable body is at a predetermined position, n+1 or more of the plurality of measurement points are positioned to be within the predetermined width on the reflection surface.

According to this apparatus, of the plurality of measurement points that the measurement device has, n points (wherein, n is an integer of two or more) or more are positioned within the predetermined width on the reflection surface, and when the movable body is at a predetermined position, n+1 points or more are positioned within the predetermined width on the reflection surface, Therefore, it becomes possible to measure positional information of the movable body in the third direction orthogonal to the predetermined plane in at least one measurement point. Accordingly, even if abnormality occurs in a part of the measurement of n points positioned within the predetermined width on the reflection surface or n+1 points when the movable body is at the predetermined position, it becomes possible to measure the positional information of the movable body in the third direction, unfailingly, with the remaining measurement points.

According to a second aspect of the present invention, there is provided a second movable body which substantially moves along a predetermined plane, the apparatus comprising: a reflection surface which is arranged at one of the movable body and the outside of the movable body, with a first direction within a plane parallel to the predetermined plane serving as a longitudinal direction, and having a predetermined width in a second direction orthogonal to the first direction; and a measurement device which measures positional information of the reflection surface in a third direction orthogonal to the predetermined plane at a plurality of measurement points placed on the reflection surface, whereby the measurement device has a plurality of head sets including a first head which irradiates a measurement beam on a first measurement point and a second head which irradiates a measurement beam on the first measurement point or in its vicinity.

According to this apparatus, the measurement device has a plurality of head sets including a first head which irradiates a measurement beam on a first measurement point of the plurality of measurement points that the measurement device has, and a second head which irradiates a measurement beam on the first measurement point or in its vicinity. Therefore, of the first head and the second head included in the head set, even if abnormality occurs in one of the heads, because the other head can be used, the head set stably irradiates measurement beams on the scale and measures the positional information of the movable body in the third direction orthogonal to the predetermined plane. Accordingly, by using the measurement device which has the plurality of head sets, it becomes possible to unfailingly measure the positional information of the movable body in the third direction.

According to a third aspect of the present invention, there is provided a third movable body apparatus including a movable body which substantially moves along a predetermined plane, the apparatus comprising: a measurement device which measures positional information of the movable body in a direction orthogonal to the predetermined plane, at a plurality of measurement points placed in a movement range of the movable body, whereby the measurement device has a plurality of heads which generate measurement information by irradiating a measurement beam on at least one of the plurality of measurement points when the movable body is located at a predetermined position.

According to this apparatus, the measurement device has a plurality of heads which generate measurement information by irradiating a measurement beam on at least one of the plurality of measurement points when the movable body is located at a predetermined position. Therefore, it becomes possible to measure positional information of the movable body in the third direction orthogonal to the predetermined plane using at least one head. Accordingly, even if abnormality occurs in a part of the plurality of heads, it becomes possible to measure the positional information of the movable body unfailingly in the third direction within the predetermined plane, using another head in the remaining heads.

According to a fourth aspect of the present invention, there is provided a pattern formation apparatus that forms a pattern on an object, the apparatus comprising: a patterning device which forms a pattern on the object, and the movable body apparatus according to the present invention (to be precise, any one of the first, second, or third movable body apparatus) in which the object is mounted on the movable body.

According to this apparatus, a pattern is generated by the patterning device on the object, which is mounted on a movable body that configures a part of the movable body apparatus of the present invention and can unfailingly measure the position information in the third direction orthogonal to the predetermined plane Accordingly, it becomes possible to form a pattern on the object with good precision.

According to a fifth aspect of the present invention, there is provided an exposure apparatus that forms a pattern on an object by irradiating an energy beam, the apparatus comprising: a patterning device that irradiates the energy beam on the object; the movable body apparatus according to the present invention in which the object is mounted on the movable body, and a driver which drives the movable body to make the object relatively move with respect to the energy beam.

According to this apparatus, to make the object relatively move with respect to the energy beam irradiated on the object from the patterning device, the driver drives the movable body on which the object is mounted with good precision. Accordingly, it becomes possible to form a pattern on the object with good precision by scanning exposure.

According to a sixth aspect of the present invention, there is provided a device manufacturing method which uses the exposure apparatus according to the present invention.

BRIEF DESCRIPTION OF THE DRAWINGS

In the accompanying drawings:

FIG. **1** is a view schematically showing the configuration of an exposure apparatus related to an embodiment;

FIG. **2**A is a planar view showing a wafer stage, and FIG. **2**B is a planar view showing a measurement stage;

FIG. **3** is a view used to explain a placement of measurement axes of an interferometer system of the exposure apparatus in FIG. **1**, and is a planar view of a stage device is, partially omitted;

FIG. **4** is a view showing a placement of various measurement systems which the exposure apparatus in FIG. **1** is equipped with;

FIG. **5** is a view showing a placement of an encoder head (an X head and a Y head) and an alignment system;

FIG. **6** is a view showing a placement of a Z head and a multipoint AF system;

FIG. **7** is a block diagram showing a main configuration of a control system of the exposure apparatus in FIG. **1**;

FIG. **8** is a view used to describe position measurement of a wafer table in a Z-axis direction and a tilt direction by a plurality of Z heads, and a switching of the Z heads;

FIGS. **9**A to **9**C are views used to explain focus mapping;

FIGS. **10**A and **10**B are views used to explain a first and second modified example of the surface position measurement system, respectively;

FIGS. **11**A and **11**B are views used to explain a third and fourth modified example of the surface position measurement system, respectively, and

FIG. **12** is a view used to explain other modified examples of the surface position measurement system.

DESCRIPTION OF THE EMBODIMENTS

An embodiment of the present invention will be described below, with reference to FIGS. **1** to **9**C.

FIG. **1** shows a schematic configuration of an exposure apparatus **100** in the embodiment. Exposure apparatus **100** is a projection exposure apparatus by the step-and-scan method, or a so-called scanner. As discussed later on, in the embodiment, a projection optical system PL is arranged, and in the description below, a direction parallel to an optical axis AX of projection optical system PT will be described as the z-axis direction, a direction within a plane orthogonal to the Z-axis direction in which a reticle and a wafer are relatively scanned will be described as the Y-axis direction, a direction orthogonal to the Z-axis and the Y-axis will be described as the X-axis direction, and rotational (inclination) directions around the X-axis, the Y-axis, and the z-axis will be described as θx, θy, and θz directions, respectively.

Exposure apparatus **100** is equipped with an illumination system **10**, a reticle stage RST, a projection unit PU, a stage device **50** having a wafer stage WST and a measurement stage MST, and a control system of these parts. Although a part of the configuration is different such as the configuration of the encoder system which will be described later on, as a whole, exposure apparatus **100** is configured similar to the exposure apparatus disclosed in the pamphlet of International Publication No. 2007/097379 (and the corresponding U.S. patent Application Publication No. 2008/0088843) previously described. Accordingly, in the description below, the explanation given for each component will be simplified, except when especially necessary. Incidentally, in FIG. **1**, a wafer W is mounted on wafer stage WST.

Illumination system **10** includes a light source, an illuminance uniformity optical system, which includes an optical integrator and the like, an illumination optical system that has a reticle blind and the like (none of which are shown), as is disclosed in, for example, U.S. patent Application Publication No. 2003/0025890 and the like. Illumination system **10** illuminates a slit-shaped illumination area IAR, which is set on reticle R with a reticle blind (a masking system), by an illumination light (exposure light) IL with a substantially uniform illuminance. In this case, as illumination light IL, for example, an ArF excimer laser beam (wavelength 193 nm) is used.

On reticle stage RST, reticle R on which a circuit pattern or the like is formed on its pattern surface (the lower surface in FIG. **1**) is fixed, for example, by vacuum chucking. Reticle stage RST is finely drivable within an XY plane, for example, by a reticle stage drive section **11** (not shown in FIG. **1**, refer to FIG. **7**) that includes a linear motor or the like, and reticle stage RST is also drivable in a scanning direction (in this case, the Y-axis direction, which is the lateral direction of the page surface in FIG. **1**) at a predetermined scanning speed.

The positional information (including rotation information in the θz direction) of reticle stage RST in the XY plane (movement plane) is constantly detected, for example, at a resolution of around 0.25 nm by a reticle laser interferometer (hereinafter referred to as a "reticle interferometer") **116**, via a movable mirror **15** (the mirrors actually arranged are a Y movable mirror (or a retro reflector) that has a reflection surface which is orthogonal to the Y-axis direction and an X movable mirror that has a reflection surface orthogonal to the X-axis direction). The measurement values of reticle interferometer **116** are sent to a main controller **20** (not shown in FIG. **1**, refer to FIG. **7**).

Projection unit PU is placed below reticle stage PST in FIG. **1**. Projection unit PU includes a barrel **40**, and projection optical system PL that has a plurality of optical elements which are held in a predetermined positional relation inside barrel **40**. As projection optical system PL, for example, a dioptric system is used, consisting of a plurality of lenses (lens elements) that is disposed along an optical axis AX, which is parallel to the Z-axis direction. Projection optical system PL is, for example, a both-side telecentric dioptric system that has a predetermined projection magnification (such as one-quarter, one-fifth, or one-eighth times). Therefore, when illumination light IL from illumination system **10** illuminates illumination area IAR, illumination light IL that has passed through reticle R which is placed so that its pattern surface substantially coincides with a first plane (an object plane) of projection optical system PL forms a reduced image of the circuit pattern (a reduced image of a part of the circuit pattern) of reticle R formed within illumination area IAR, via projection optical system PL (projection unit PU), in an area (hereinafter, also referred to as an exposure area) IA conjugate to illumination area IAR on wafer W whose surface is coated with a resist (a photosensitive agent) and is placed on a second plane (an image plane) side of projection optical system PL. And by reticle stage RST and wafer stage WST being synchronously driven, reticle R is relatively moved in the scanning direction (the Y-axis direction) with respect to illumination area ITAR (illumination light IL) while wafer W is relatively moved in the scanning direction (the Y-axis direction) with respect to exposure area IA (illumination light IL), thus scanning exposure of a shot area (divided area) on wafer W is performed, and the pattern of reticle R is transferred onto the shot area. That is, in the embodiment, the pattern is generated on wafer W according to illumination system **10**, reticle R, and projection optical system PL, and then by the exposure of the sensitive layer (resist layer) on wafer W with illumination light IL, the pattern is formed on wafer W.

In exposure apparatus **100** of the embodiment, a local liquid immersion device B is installed to perform exposure by a liquid immersion method. Local liquid immersion device **8** includes a liquid supply device **5**, a liquid recovery device **6** (both of which are not shown in FIG. **1**, refer to FIG. **7**), a liquid supply pipe **31**A, a liquid recovery pipe **31**B, a nozzle unit **32** and the like. As shown in FIG. **1**, nozzle unit **32** is supported in a suspended state by a mainframe (not shown) holding projection unit PU, so that the periphery of the lower end portion of barrel **40** that holds an optical element closest to the image plane side (the wafer W side) constituting projection optical system PL, in this case, a lens (hereinafter also referred to as a tip lens) **191**, is enclosed. In the embodiment, as shown in FIG. **1**, nozzle unit **32** is set so that its lower end surface is on a substantially flush surface with the lower end surface of tip lens **191**. Further, nozzle unit **32** is equipped with a supply opening and a recovery opening of liquid Lq, a lower surface to which wafer W is placed facing and at which the recovery opening is arranged, and a supply flow channel and a recovery flow channel that are connected to a liquid supply pipe **31**A and a liquid recovery pipe **31**B respectively. Liquid supply pipe **31**A and liquid recovery pipe **31**B are slanted by around 45 degrees relative to an X-axis direction and Y-axis direction in a planar view (when viewed from above) as shown in FIG. **4**, and are placed symmetric to a straight line (a reference axis) LV which passes through the center (optical axis AX of projection optical system PL, coinciding with the center of exposure area IA previously described in the embodiment) of projection unit PU and is also parallel to the Y-axis.

Liquid supply pipe **31**A connects to liquid supply device **5** (not shown in FIG. **1**, refer to FIG. **7**), and liquid recovery pipe **31**B connects to liquid recovery device **6** (not shown in FIG. **1**, refer to FIG. **7**). In this case, in liquid supply device **5**, a tank to store the liquid, a compression pump, a temperature controller, a valve for controlling the flow amount of the liquid, and the like are equipped. In liquid recovery device **6**, a tank to store the liquid which has been recovered, a suction pump, a valve for controlling the flow amount of the liquid, and the like are equipped.

Main controller **20** controls liquid supply device **5** (refer to FIG. **7**), and supplies liquid between tip lens **191** and wafer W via liquid supply pipe **31**A, as well as control liquid recovery device **6** (refer to FIG. **7**), and recovers liquid from between tip lens **191** and wafer W via liquid recovery pipe **31**B. During the operations, main controller **20** controls liquid supply device **5** and liquid recovery device **6** so that the quantity of water supplied constantly equals the quantity of water which has been recovered. Accordingly, in the space between tip lens **191** and wafer W, a constant quantity of liquid Lq (refer to FIG. **1**) is held constantly replaced, and by this, a liquid immersion area **14** (for example, refer to FIG. **8**) is formed. Incidentally, in the case measurement stage MST which will be described later on is positioned below projection unit PU, liquid immersion area **14** can be formed similarly in the space between tip lens **191** and a measurement table described later on.

In the embodiment, as the liquid described above, pure water (hereinafter, it will simply be referred to as "water" besides the case when specifying is necessary) that transmits the ArF excimer laser light (light with a wavelength of 193 nm) is to be used. Incidentally, refractive index n of the water with respect to the ArF excimer laser light is around 1.44. In the water the wavelength of illumination light IL is 193 nm×1/n, shorted to around 134 nm.

As shown in FIG. **1**, stage device **50** is equipped with a wafer stage WST and a measurement stage MST placed above a base board **12**, a measurement system **200** (refer to FIG. **7**) which measures positional information of the stages WST and MST, a stage drive system **124** (refer to FIG. **7**) which drives stages WST and MST and the like. Measurement system **200** includes an interferometer system **118**, an encoder system **150**, and a surface position measurement system **180** as shown in FIG. **7**. Incidentally, details on interferometer system **118**, encoder system **150** and the like will be described later in the description.

Wafer stage WST and measurement stage MST are supported above base board **12**, via a clearance of around several μm by a plurality of noncontact bearings (not shown) fixed to each of the bottom surfaces, such as, for example, air pads. Further, stages WST and MST are drivable independently within the XY plane, by stage drive system **124** (refer to FIG. **7**) which includes a linear motor and the like.

Wafer stage WST includes a stage main section **91**, and a wafer table WTB that is mounted on stage main section **91**. Wafer table WTS and stage main section **91** are configured drivable in directions of six degrees of freedom (X, Y, Z, θx, θy, and θz) with respect to base board **12** by a drive system including a linear motor and a Z leveling mechanism (including a voice coil motor and the like).

In the center of the upper surface of wafer table WTB, a wafer holder (not shown) is arranged which holds wafer w by vacuum suction or the like. On the outer side of the wafer holder (mounting area of the wafer), as shown in FIG. **2**A, a plate (a liquid repellent plate) **28** is arranged that has a circular opening one size larger than the wafer holder formed in the center, and also has a rectangular outer shape (contour). A liquid repellent treatment against liquid Lq is applied to the surface of plate **28** (a liquid repellent surface is formed). Incidentally, plate **28** is installed on the wafer table WTB upper surface, so that its entire surface or a part of the surface becomes flush with the surface of wafer W.

Plate **28** has a first liquid repellent area **28***a* having a rectangular outer shape (contour) with the circular opening described above formed in the center, and a second liquid repellent area **28***b* having a rectangular frame (loop) shape placed around the first liquid repellent area. Incidentally, in the embodiment, because water is used as liquid Lq as is previously described, hereinafter, the first liquid repellent area **28***a* and the second liquid repellent area **28***b* will also be referred to as a first water repellent plate **28***a* and a second water repellent plate **28***b*.

On an end on the +Y side of the first water repellent plate **28***a*, a measurement plate **30** is arranged. On measurement plate **30**, a fiducial mark FM is arranged in the center, and a pair of aerial image measurement slit patterns (slit-shaped measurement patterns) SL is arranged with the mark in between. And, in correspondence with each aerial image measurement slit pattern SL, a light-transmitting system (not shown) which guides illumination light IL passing through the slit patterns outside wafer stage WST (a photodetection system arranged in measurement stage MST which will be described later on) is arranged.

On second liquid repellent area **28***b*, scales for an encoder system (to be described later) are formed. More specifically, in areas on one side and the other side in the X-axis direction of the second water repellent plate **28***b* (both sides in the horizontal direction in FIG. **2**A), Y scales **39**Y_1 and **39**Y_2 are formed, respectively. Y scales **39**Y_1 and **39**Y_2 are each composed of a reflective grating (for example, a diffraction grating) having a periodic direction in the Y-axis direction in which grid lines **38** having the longitudinal direction in the X-axis direction are formed in a predetermined pitch along a direction parallel to the Y-axis (the Y-axis direction). Similarly, in areas on one side and the other side in the Y-axis direction of the second water repellent plate **28***b* (both sides in the vertical direction in FIG. **5**A), X scales **39**X_1 and **39**X_2 are formed, respectively, in a state where the scales are placed between Y scales **39**Y_1 and **39**Y_2. X scales **39**X_1 and **39**X_2 are each composed of a reflective grating (for example, a diffraction grating) having a periodic direction in the X-axis direction in which grid lines **37** having the longitudinal direction in the Y-axis direction are formed in a predetermined pitch along a direction parallel to the X-axis (the X-axis direction). The pitch of grid lines **37** and **38**, for example, is set to 1 μm. Incidentally, in FIG. **2**A, the pitch of the gratings is illustrated larger than the actual pitch for the sake of convenience. The same is true also in other drawings.

Incidentally, in order to protect the diffraction grating, it is also effective to cover the grating with a glass plate with low thermal expansion that has water repellency. In this case, as the glass plate, a plate whose thickness is the same level as the wafer, such as for example, a plate 1 mm thick, can be used, and the plate is set on the upper surface of wafer table WTB so that the surface of the glass plate becomes the same height (surface position) as the wafer surface.

Further, to the −Y end surface and the −X end surface of wafer table WTB, mirror-polishing is applied, respectively, and as shown in FIG. **2**A, reflection surfaces **17***a* and **17***b* are formed for interferometer system **118** which will be described later in the description.

Measurement stage MST includes a stage main section **92** driven in the XY plane by a linear motor and the like (not shown), and a measurement table MTB mounted on stage main section **92**, as shown in FIG. **1**. Measurement stage MST is configured drivable in at least directions of three degrees of freedom (X, Y, and θz) with respect to base board **12** by a drive system (not shown).

Incidentally, in FIG. **7**, the drive system of wafer stage WST and the drive system of measurement stage MST are included and are shown as stage drive system **124**.

Various measurement members are arranged at measurement table MTB (and stage main section **92**). As such measurement members, for example, as shown in FIG. **25**, members such as an uneven illuminance measuring sensor **94** that has a pinhole-shaped light-receiving section which receives illumination light IL on an image plane of projection optical system PL, an aerial image measuring instrument **96** that measures an aerial image (projected image) of a pattern projected by projection optical system PL, a wavefront aberration measuring instrument **98** by the Shack-Hartman method that is disclosed in, for example, the pamphlet of International Publication No. 2003/065428, an illuminance monitor (not shown) and the like are employed. Further, in stage main section **92**, a pair of photodetection systems (not shown) is arranged in a placement facing the pair of light-transmitting systems (not shown) previously described.

In the embodiment, in a state where wafer stage WST and measurement stage MST are in proximity within a predetermined distance in the Y-axis direction (including a contact state), illumination lights IL that has been transmitted through each aerial image measurement slit pattern SL of measurement plate on wafer stage WST axe guided by each light-transmitting system (not shown) and are received by light-receiving elements of each photodetection system (not shown) within measurement stage MST.

On the −Y side end surface of measurement table MTB, a fiducial bar (hereinafter, shortly referred to as an "FD bar") **46** is arranged extending in the X-axis direction, as shown in FIG. **2**B. In the vicinity of the end portions on one side and the other side in the longitudinal direction of FD bar **46***r* a reference grating (for example, a diffraction grating) **52** whose periodic direction is the Y-axis direction is respectively formed, placed symmetric to a center line CL. Further, on the upper surface of FD bar **46**, a plurality of reference marks M is formed As each of reference marks M, a two-dimensional mark having a size that can be detected by a primary alignment system and secondary alignment systems (to be described later) is used. Incidentally, the surface of FD bar **46** and the surface of measurement table MTB are also covered with a liquid repellent film (water repellent film).

On the +Y end surface and the −X end surface of measurement table MTB, reflection surfaces **19***a* and **19***b* are formed similar to wafer table WTB as is previously described (refer to FIG. **2**B).

In exposure apparatus **100** of the embodiment, a primary alignment system AL_1 having a detection center at a position spaced apart from optical axis AX of projection optical system PL at a predetermined distance on the −Y side is placed on reference axis LV previously described as shown in FIGS. **4** and **5**. Primary alignment system AL**1** is fixed by the lower surface of a (not shown) mainframe. On one side and the other side in the X-axis direction with primary alignment system AL**1** in between, secondary alignment systems $AL\mathbf{2}_1$ and $AL\mathbf{2}_2$, and $AL\mathbf{2}_3$ and $AL\mathbf{2}_4$ whose detection centers are substantially symmetrically placed with respect to straight line LV are severally arranged. Secondary alignment systems $AL\mathbf{2}_1$ to $AL\mathbf{2}_4$ are fixed via a movable support member to the lower surf ace of the mainframe (not shown), and by drive mechanisms $\mathbf{60}_1$ to $\mathbf{60}_4$ (refer to FIG. **7**), their detection areas (or detection center) can be driven independently in the X-axis direction. Accordingly, the relative positions of the detection areas of primary alignment system AL**1** and secondary alignment systems $AL\mathbf{2}_1$, $AL\mathbf{2}_2$, $AL\mathbf{2}_3$ and $AL\mathbf{2}_4$ are adjustable in the X-axis direction. Incidentally, a straight line (a reference axis) LA which passes through the detection center of primary alignment system AL**1** and is parallel to the X-axis shown in FIG. **4** and the like coincides with the optical axis of a measurement beam **86** from interferometer **127** previously described.

In the embodiment, as each of alignment systems AL**1** and $AL\mathbf{2}_1$ to $AL\mathbf{2}_4$, for example, an FIA (Field Image Alignment) system by an image processing method is used. The imaging signals from each of alignment systems AL**1** and $AL\mathbf{2}_1$ to $AL\mathbf{2}_4$ are supplied to main controller **20**, via a signal processing system (not shown).

Incidentally, each of the alignment systems described above is not limited to the FIA system, and an alignment sensor, which irradiates a coherent detection light to a subject mark and detects a scattered light or a diffracted light generated from the subject mark or makes two diffracted lights (for example, diffracted lights of the same order or diffracted lights being diffracted in the same direction) generated from the subject mark interfere and detects an interference light, can naturally be used alone or in combination as needed.

Next, a configuration and the like of interferometer system **118** (refer to FIG. **7**), which measures the positional information of wafer stage WST and measurement stage MST, will be described.

Interferometer system **118** includes a Y interferometer **16**, X interferometers **126**, **127**, and **128***r* and Z interferometers **43**A and **43**B for position measurement of wafer stage WST, and a Y interferometer **18** and an X interferometer **130** for position measurement of measurement stage MST, as shown in FIG. **3**. Y interferometer **16** and the three X interferometers **126**, **127**, and **128** each irradiate interferometer beams (measurement beams) B**4** (B$\mathbf{4}_1$, B$\mathbf{4}_2$), B**5** (B$\mathbf{5}_1$, a B$\mathbf{5}_2$), B**6**, and **37** on reflection surfaces **17***a* and **17***b* of wafer table WTB. And Y interferometer **16** and the three X interferometers **126**, **127**, and **128** each receive the reflected lights, and measure the positional information of wafer stage WST in the XY plane, and supply the positional information which has been measured to main controller **20**.

Incidentally, for example, X interferometer **126** irradiates at least three measurement beams parallel to the X-axis including a pair of measurement beams B$\mathbf{5}_1$ and B$\mathbf{5}_2$ which passes through optical axis (in the embodiment, also coinciding with the center of exposure area IA previously described) AX of projection optical system PL and is symmetric about a straight line (reference axis LH (refer to FIGS. **4**, **5** and the like)) parallel to the X-axis. Further, Y interferometer **16** irradiates at least three measurement beams parallel to the Y-axis including a pair of measurement beams B$\mathbf{4}_1$ and B$\mathbf{4}_2$ which is symmetric about reference axis LV previously described on reflection surface **17***a* and a movable mirror **41** (to be described later on). As described, in the embodiment, as each interferometer, a multiaxial interferometer which a plurality of measurement axis is used, with an exception for a part of the interferometers (for example, interferometer **128**). Therefore, in addition to the X, Y positions of wafer table WTB (wafer stage WST), main controller **20** can also compute rotation information (that is, pitching amount) in the θx direction, rotation information (that is, rolling amount) in the θy direction, and rotation information (that is, yawing amount) in the θz direction, based on the measurement results of Y interferometer **16** and either X interferometers **126** or **127**.

Further, as shown in FIG. **1**, movable mirror **41** having a concave-shaped reflection surface is attached to the side surface on the −Y side of stage main section **91**. As it can be seen from FIG. **2**A, movable mirror **41** is designed so that the length in the X-axis direction is longer than reflection surface **17***a* of wafer table WTB.

A pair of Z interferometers **43**A and **43**B are arranged (refer to FIGS. **1** and **3**), facing movable mirror **41**. Z interferometers **43**A and **43**B irradiate two measurement beams B**1** and B**2**, respectively, on fixed mirrors **47**A and **478**, which are fixed, for example, on a frame (not shown) supporting projection unit PU, via movable mirror **41**. And by receiving each reflected light, Z interferometers **43**A and **43**B measure the optical path length of measurement beams B**1** and B**2**. And from the results, main controller **20** computes the position of wafer stage WST in four degrees of freedom (Y, Z, θy, and θz) directions.

In the embodiment, position information within the XY plane (including the rotation information in the θz direction) of wafer stage WST (wafer table WTB) is mainly measured by an encoder system (to be described later). Interferometer system **118** is used when wafer stage WST is positioned outside the measurement area (for example, near unloading position UP and loading position LP as shown in the drawings such as FIG. **4**) of the encoder system. Further, interferometer system **118** is used secondarily when correcting (calibrating) a long-term variation (for example, temporal deformation of the scale) of the measurement results of the encoder system and the like. As a matter of course, all positional information of wafer stage WST (wafer table WTB) can be measured using both interferometer system **118** and the encoder system together.

Y interferometer **18** and X interferometer **130** of interferometer system **118** irradiate interferometer beams (measurement beams) on reflection surfaces **19***a* and **19***b* of measurement table MTB as shown in FIG. **3**, and measure the positional information of measurement stage MST (including, for example, at least the positional information in the X-axis and the Y-axis directions and the rotation information in the θz direction) by receiving the respective reflected lights, and supply the measurement results to main controller **20**.

Next, the structure and the like of encoder system **150** (refer to FIG. **7**) which measures the positional information of wafer stage WST in the XY plane (including rotation information in the θz direction) will be described.

In exposure apparatus **200** of the embodiment, as shown in FIG. **4**, four head units **62**A to **62**D are placed in a state extending from nozzle unit **32** in four directions. These head units **62**A to **62**D are fixed to the mainframe (not shown) holding projection unit UP in a suspended state, via a support member.

Head units **62**A and **62**C are equipped with a plurality of (nine, in this case) Y heads $\mathbf{65}_1$ to $\mathbf{65}_9$ and $\mathbf{64}_1$ to $\mathbf{64}_9$, as shown in FIG. **5**, respectively. In detail, head units **62**A and **62**C are equipped with a plurality of (seven, in this case) Y heads $\mathbf{65}_5$ to $\mathbf{65}_9$ and $\mathbf{64}_1$ to $\mathbf{64}_7$ placed at a distance WD on reference axis LH previously described, respectively, and a plurality of (two, in this case) Y heads $\mathbf{65}_1$ and $\mathbf{65}_2$, and $\mathbf{64}_9$ and $\mathbf{64}_9$ placed at distance WD a predetermined distance away from reference axis LH in the −Y direction on the −Y side of nozzle unit **32** in parallel with reference axis LH, respectively. Incidentally, the distance between Y heads $\mathbf{65}_2$ and $\mathbf{65}_3$ and Y heads $\mathbf{64}_7$ and $\mathbf{64}_8$ in the X-axis direction is also set to WD. Hereinafter, Y heads $\mathbf{65}_1$ to $\mathbf{65}_9$ and $\mathbf{64}_1$ to $\mathbf{64}_9$ will also be described as Y heads **65** and **64**, respectively, as necessary.

Head unit **62**A constitutes a multiple-lens (nine-lens, in this case) Y linear encoder (hereinafter, shortly referred to as a “Y encoder” or an “encoder” as appropriate) **70**A (refer to FIG. **7**) that measures the position of wafer stage WST (wafer table WTB) in the Y-axis direction (Y position), using Y scale $\mathbf{39}\mathrm{Y}_1$ previously described. Similarly, head unit **62**C constitutes a multiple-lens (nine-lens, in this case) Y linear encoder **70**C (refer to FIG. **7**) that measures the Y position of wafer stage WST (wafer table WTB) using Y scale $\mathbf{39}\mathrm{Y}_2$ described above. In this case, distance WD in the X-axis direction of the nine Y heads **64** and **65** (to be more accurate, the irradiation points of the measurement beams generated by Y heads **65** and **64** on the scale) that head units **62**A and **62**C are each equipped with, is set slightly narrower than half the width (to be more precise, the length of grid line **38**) of Y scales $\mathbf{39}\mathrm{Y}_1$ and $\mathbf{39}\mathrm{Y}_2$ in the X-axis direction. Accordingly, of each nine Y heads **65** and **64**, at least two heads each constantly face the corresponding Y scales $\mathbf{39}\mathrm{Y}_1$ and $\mathbf{39}\mathrm{Y}_2$ at the time of the exposure and the like. More specifically, of the measurement beams which each nine Y heads **65** and **64** generate, at least two measurement beams each can be irradiated on the corresponding Y scales $\mathbf{39}\mathrm{Y}_1$ and $\mathbf{39}\mathrm{Y}_2$.

As shown in FIG. **5**, head unit **62**B is placed on the +Y side of nozzle unit **32** (projection unit PU), and is equipped with a plurality of, in this case, seven X heads $\mathbf{66}_8$ to $\mathbf{66}_{14}$ that are placed on reference axis LV previously described along Y-axis direction at distance WD. Further, head unit **62**D is placed on the −Y side of primary alignment system AL**1**, on the opposite side of head unit **62**B via nozzle unit **32** (projection unit PU), and is equipped with a plurality of, in this case, seven X heads $\mathbf{66}_1$ to $\mathbf{66}_7$ that are placed on reference axis LV at distance WD. Hereinafter, X heads $\mathbf{66}_1$ to $\mathbf{66}_{14}$ will also be described as X heads **66**, as necessary.

Head unit **62**B constitutes a multiple-lens (seven-lens, in this case) X linear encoder (hereinafter, shortly referred to as an “X encoder” or an “encoder” as needed) **703** (refer to FIG. **7**) that measures the position in the X-axis direction (the X-position) of wafer stage WST (wafer table WTB) using X scale $\mathbf{39}\mathrm{X}_1$ previously described. Further, head unit **62**D constitutes a multiple-lens (seven-lens, in this case) X linear encoder **70**D (refer to FIG. **7**) that measures the X-position of wafer stage WST (wafer table WTB) using X scale $\mathbf{39}\mathrm{X}_2$ previously described.

Here, distance WD between adjacent X heads **66** (to be more accurate, the irradiation point of the measurement beam generated by X head **66** on the scale) in the Y-axis direction that are equipped in each of head units **62**B and **62**D is set shorter than halt the width of X scales $\mathbf{39}\mathrm{X}_1$ and $\mathbf{39}\mathrm{X}_2$ (to be more accurate, the length of grid line **37**) in the Y-axis direction. Accordingly, of the X heads **66** which head units **62**B and **62**D are equipped with, at least two heads face the corresponding X scales $\mathbf{39}\mathrm{X}_1$ and $\mathbf{39}\mathrm{X}_2$ at the time of the exposure and the like, except for times such as switching (linkage) which will be described later. More specifically, of the measurement beams which each seven X heads **66** generate, at least two measurement beams each can be irradiated on the corresponding X scales $\mathbf{39}\mathrm{X}_1$ and $\mathbf{39}\mathrm{X}_2$. Incidentally, the distance between X head $\mathbf{66}_8$ farthest to the −Y side of head unit **62**B and X head $\mathbf{66}_7$ farthest to the +Y side of head unit **62**D is set slightly narrower than the width of wafer table WTB in the Y-axis direction so that switching (linkage described below) becomes possible between the two X heads by the movement of wafer stage WST in the Y-axis direction.

Incidentally, in the placement of X head **66** in the embodiment, on the switching (linkage) described above, only X head $\mathbf{66}_8$ farthest to the −Y side among X heads **66** belonging to head unit **62**B faces the corresponding X scale $\mathbf{39}\mathrm{X}_1$, and only X head $\mathbf{66}_7$ farthest to the +Y side among X heads **66** belonging to head unit **62**D fates the corresponding X scale $\mathbf{39}\mathrm{X}_2$. More specifically, only one each of the X heads **66** faces X scales $\mathbf{39}\mathrm{X}_1$ and $\mathbf{39}\mathrm{X}_2$. Therefore, the distance between head unit **62**B and **62**D can be narrower than distance WD, and at least one of X heads $\mathbf{66}_8$ and $\mathbf{66}_9$ can be made to face the corresponding X scales at the same time, as well as X head $\mathbf{66}_8$ and X head $\mathbf{66}_7$ which face the corresponding X scales also at the time of switching (linkage).

In the embodiment, furthermore, as shown in FIG. **4**, head units **62**E and **62**F are respectively arranged a predetermined distance away on the −Y side of head units **62**C and **62**A. These head units **62**E and **62**F are fixed to the mainframe (not shown) holding projection unit UP in a suspended state, via a support member.

Head unit **62**E is equipped with seven Y heads $\mathbf{67}_1$ to $\mathbf{67}_7$, as shown in FIG. **5**. More particularly, head unit **62**E is equipped with five Y heads $\mathbf{67}_1$ to $\mathbf{67}_5$ placed on the −X side of the secondary alignment system $\mathrm{AL}\mathbf{2}_1$ on reference axis LA at substantially the same distance as distance WD previously described, and two Y heads $\mathbf{67}_6$ and $\mathbf{67}_7$ placed on the +Y side of the secondary alignment system $\mathrm{AL}\mathbf{2}_1$ a predetermined distance away in the +Y direction from reference axis LA, at distance WD parallel to reference axis LA. Incidentally, the distance between Y heads $\mathbf{67}_5$ and $\mathbf{67}_6$ in the X-axis direction is also set to WD. Hereinafter, Y heads $\mathbf{67}_3$ to $\mathbf{67}_7$ will also be described, appropriately, as Y head **67**.

Head unit **62**F is symmetrical to head unit **62**E with respect to reference axis LV previously described, and is equipped with seven Y heads **681** to **687** which are placed in symmetry to the seven Y heads **67** with respect to reference axis LV. Hereinafter, Y heads **68**, to **687** will also be described, appropriately, as Y head **68**.

On alignment operation and the like, at least two each of Y heads **67** and **68** face Y scales **39**Y_2 and **39**Y_1, respectively. More specifically, of the measurement beams which each seven Y heads **67** and **68** generate, at least two measurement beams each can be constantly irradiated on Y scales **39**Y_1 and **39**X_2 at the time of alignment and the like. The Y position (and θz rotation) of wafer stage WST is measured by these Y heads **67** and **68** (more specifically, Y encoders **70**E and **70**F configured by Y heads **67** and **68**).

Further, in the embodiment, at the time of baseline measurement and the like of the secondary alignment system, Y head **67**$_5$ and **68**$_3$ which are adjacent to the secondary alignment systems AL**2**$_1$ and AL**2**$_4$ in the X-axis direction face the pair of reference gratings **52** of FD bar **46**, respectively, and by Y heads **67** and **68** that face the pair of reference gratings **52**, the Y position of FD bar **46** is measured at the position of each reference grating **52**. In the description below, the encoders configured by Y heads **67** and **68** which face a pair of reference gratings **52**, respectively, are referred to as Y linear encoders (also shortly referred to as a "Y encoder" or an "encoder" as needed) **70**E_2 and **70**F_2. Further, for identification, Y encoders **70**E and **70**F configured by Y heads **67** and **68** that face Y scales **39**Y_2 and **39**Y_1 described above, respectively, will be referred to as Y encoders **70**E_1 and **70**F_1.

The measurement values of linear encoders **70**A to **70**F described above is supplied to main controller **20**, and main controller **20** controls the position within the XY plane of wafer stage WST based on three measurement values of linear encoders **70**A to **70**D or on three measurement values of encoders **70**B, **70**D, **70**E_1, and **70**F_1, and also controls the rotation in the an direction of FD bar **46** based on the measurement values of linear encoders **70**E_2 and **70**F_2.

In exposure apparatus **100** of the embodiment, as shown in FIGS. **4** and **6**, a multipoint focal position detecting system (hereinafter, shortly referred to as a "multipoint AF system") by an oblique incident method is arranged, which is composed of an irradiation system **90***a* and a photodetection system **90***b*, having a configuration similar to the one disclosed in, for example, U.S. Pat. No. 5,448,332 and the like. In the embodiment, as an example, irradiation system **90***a* is placed on the +Y side of the −X end portion of head unit **62**E previously described, and photodetection system **90***b* is placed on the +Y side of the +X end portion of head unit **62**F previously described in a state of opposing irradiation system **90***a*. The multipoint AF system (**90***a*, **90***b*) is fixed to the lower surface of the mainframe (not shown) holding projection unit PU previously described.

A plurality of detection points of the multipoint AF system (**90***a*, **90***b*) are placed at a predetermined distance along the X-axis direction on the surface to be detected. In the embodiment, the plurality of detection points are placed, for example, in the arrangement of a matrix having one row and M columns (M is a total number of detection points) or having two rows and N columns (N=M/2). In FIGS. **4** and **6**, the plurality of detection points to which a detection beam is severally irradiated are not individually shown, but are shown as an elongate detection area (beam area) AF that extends in the X-axis direction between irradiation system **90***a* and photodetection system **90***b*. Because the length of detection area AF in the X-axis direction is set to around the same as the diameter of wafer W, by only scanning wafer W in the Y-axis direction once, position information (surface position information) in the Z-axis direction across the entire surface of wafer W can be measured.

As shown in FIG. **6**, in the vicinity of both end portions of beam area AF of the multipoint AF system (**90***a*, **90***b*), heads **72***a* and **72***b*, and **72***c* and **72***d* of surface position sensors for Z position measurement (hereinafter, shortly referred to as "Z heads") are arranged each in a pair, in symmetrical placement with respect to reference axis LV. Z heads **72***a* to **72***d* are fixed to the lower surface of a main frame (not shown).

As Z heads **72***a* to **72***d*, for example, a head of an optical displacement sensor similar to an optical pickup used in a CD drive device is used. Z heads **72***a* to **72***d* irradiate measurement beams to wafer table WTB from above, and by receiving the reflected lights, measure the positional information (surface position information) of the surface of wafer table WTB in the Z-axis direction orthogonal to the XY plane at the irradiation point. Incidentally, in the embodiment, a configuration is employed where the measurement beams of the Z heads are reflected by the reflection grating configuring the Y scales **39**Y_2 and **39**Y_2 previously described.

Furthermore, as shown in FIG. **6**, head units **62**A and **62**C previously described are respectively equipped with Z heads **76**$_j$ and **74**$_i$ (i, j=1-9), which are nine heads each, at the same X position as Y heads **65**$_j$ and **64**$_i$ (i, j=1-9) that head units **62**A and **62**C are respectively equipped with, with the Y position shifted. In this case, Z heads **76**$_8$ to **76**$_9$ and **74**$_1$ to **74**$_5$, which are five heads each on the outer side belonging to head units **62**A and **62**C, respectively, are placed parallel to reference axis LH a predetermined distance away in the +Y direction from reference axis LH. Further, Z heads **76**$_1$ and **76**$_2$ and Z heads **74**$_8$ and **74**$_9$, which are two heads on the innermost side belonging to head units **62**A and **62**C, respectively, are placed on the +Y side of projection unit PU, and the remaining Z heads **763** and **76**$_4$, and **74**$_6$ and **74**$_7$ are placed on the −Y side of Y heads **65**$_3$ and **65**$_4$, and **64**$_6$ and **64**$_7$, respectively. And Z heads **76**$_j$ and **74**$_i$, which are nine heads each belonging to head units **62**A and **62**C, respectively, are placed symmetric to each other with respect to reference axis LV. Incidentally, as each of the Z heads **76**$_j$ and **74**$_i$, an optical displacement sensor head similar to Z heads **72***a* to **72***d* described above is used.

The distance of the nine Z heads **76** and **74** (to be more accurate, the irradiation point of the measurement beam generated by the Z heads on the scale) in the X-axis direction that are equipped in each of head units **62**A and **62**C is set equal to distance WD of Y heads **65** and **64** in the X-axis direction. Accordingly, similar to Y heads **65** and **64**, of each nine Z heads **76**$_j$ and **74**$_i$, at least two heads each constantly face the corresponding Y scales **39**Y_1 and **39**Y_2 at the time of the exposure and the like. More specifically, of the measurement beams which each nine Z heads **76**$_j$ and **74**$_i$ generate, at least two measurement beams each can be irradiated on the corresponding Y scales **39**Y_1 and **39**Y_2.

Z heads **72***a* to **72***d*, **74**$_1$ to **74**$_9$, and **76**$_1$ to **76**$_9$ connect to main controller **20** via a signal processing/selection device **170** as shown in FIG. **7**, and main controller **20** selects an arbitrary Z head from Z heads **72***a* to **72***d*, **74**$_1$ to **74**$_9$, and **76**$_1$ to **76**$_9$ via signal processing/selection device **170** and makes the head move into an operating state, and then receives the surface position information detected by the Z head which is in an operating state via signal processing/selection device **170**. In the embodiment, a surface position measurement system **180** (a part of measurement system **200**) that measures positional information of wafer stage WST in the Z-axis direction and the direction of inclination with respect to the XY plane is configured, including Z heads **72***a* to **72***d*, **74**$_1$ to **74**$_9$, and **76**$_1$ to **76**$_9$, and signal processing/selection device

170. Incidentally, in the description below, Z heads 74_1 to 74_9 and 76_1 to 76_9 will appropriately be referred to as Z heads **74** and **76**, respectively.

Furthermore, in exposure apparatus **100**, above reticle stage RST, a pair of reticle alignment detection systems **13**A and **13**B (not shown in FIG. **1**, refer to FIG. **7**) consisting of TTR (Through The Reticle) alignment systems which use lights of the exposure wavelength is arranged. Detection signals of reticle alignment detection systems **13**A and **13**B are supplied to main controller **20** via an alignment signal processing system (not shown).

FIG. **7** shows the main configuration of the control system of exposure apparatus **100**. The control system is mainly configured of main controller **20** composed of a microcomputer (or workstation) that performs overall control of the entire apparatus. Incidentally, in FIG. **7**, various sensors such as uneven illuminance measuring sensor **94**, aerial image measuring instrument **96** and wavefront aberration measuring instrument **98** that are arranged at measurement stage MST are collectively shown as a sensor group **99**.

In exposure apparatus **100** of the embodiment, because the placement of the Y scales on wafer table WTB previously described and the placement of the z heads previously described were employed, as shown in FIG. **8**, in the range where wafer stage WST moves for exposure operation, Z heads **76** and **74** which belong to head units **62**A and **62**C face Y scales $\mathbf{39}Y_1$ and $\mathbf{39}Y_2$, respectively, without fail. Incidentally, in FIG. **8**, the Z heads which face the corresponding Y scales are shown circled by a solid line.

As previously described, head units **62**A and **62**C constantly make at least two Z heads face the corresponding Y scale (to be more precise, at least two measurement beams can be constantly irradiated on the corresponding scale). Therefore, main controller **20** pairs at least two Z heads facing the Y scale and uses the pairs for head units **62**A and **62**C, respectively. Then, main controller **20** constantly monitors the measurement values of the two Z heads, and uses one of the measurement values as a representative of the pair of heads (or the head unit to which the two Z heads belong). Of the two Z heads, main controller **20**, for example, uses the head which faces the scale first as a priority head, and the head which faces the scale later on as an auxiliary head. Or, main controller **20** can use the head near the center of the scale in a direction orthogonal to the longitudinal direction as a priority head, and the remaining head can be used as an auxiliary head. Main controller **20** can normally use the measurement values of the priority head as a representative, and in the case abnormality occurs in the measurement values of the priority head, the measurement values of the auxiliary head can be used as the measurement values of the pair of heads (or head unit) in the Z-axis direction. Main controller **20** monitors the measurement values of the two head units **62**A and **62**C in the Z-axis direction according to this handling.

Main controller **20** monitors photoelectric conversion signals output by a light receiving element inside the head to inspect the correctness of the measurement result of the priority head, especially to inspect the output abnormality of the priority head due to malfunction (abnormality) of the head, and when there are no photoelectric conversion signals (when the signal intensity is zero) or when the signal intensity is at an extremely low level, main controller **20** judges that abnormality has occurred, and otherwise decides it is normal.

Therefore, in the range where wafer stage WST moves for exposure operation, by controlling each motor that configures stage drive system **124** based on the measurement results of the two head units **62**A and **62**C (the Z heads belonging to each unit), position of wafer stage WST in the Z-axis direction (the surface position of wafer table WTB) and the position of tilt direction (position in the θy direction) can be controlled in a stable manner and with high precision.

Further, when main controller **20** drives wafer stage WST in the X-axis direction as shown by an outlined arrow in FIG. **8**, the pair of Z heads **76** and **74**, which measures the surface position of wafer stage WST, is sequentially switched to an adjacent pair of heads as shown by an arrow f**1** in FIG. **8**. To enter the details, as for Z head **76**, the pair of heads is switched from the pair $\mathbf{76}_4$ and $\mathbf{76}_5$ surrounded by the circle in a solid line to the pair $\mathbf{76}_5$ and $\mathbf{76}_6$ surrounded by the circle in a dotted line, and as for Z head **74**, the pair of heads is switched from the pair $\mathbf{74}_4$ and $\mathbf{74}_5$ surrounded by the circle in a solid line to the pair $\mathbf{74}_5$ and $\mathbf{74}_6$ surrounded by the circle in a dotted line. In this case, one head ($\mathbf{76}_5$, $\mathbf{74}_5$) is common in the pair of heads before the switching and the pair of heads after the switching.

In the embodiment, in order to perform the switching (linkage) of the Z heads **76** and **74** smoothly, as is previously described, of the Z heads **76** and **74** that head units **62**A and **62**C are equipped with, the distance (twice the distance WD of adjacent heads in the X-axis direction) between the two heads to be switched (for example, in the example in FIG. **8**, Z heads $\mathbf{76}_4$ and $\mathbf{76}_6$, and $\mathbf{74}_4$ and $\mathbf{74}_6$) is set smaller than the width of Y scales $\mathbf{39}Y_1$ and $\mathbf{39}Y_2$ in the X-axis direction. In other words, distance WD of adjacent Z heads is set narrower than half the width of Y scales $\mathbf{39}Y_1$ and $\mathbf{39}Y_2$ in the X-axis direction.

In the embodiment, a method is employed where the head used for measuring the Z position of wafer stage WST is switched from a pair of heads (for example, Zh**1** and Zh**2**) to another pair of heads (Zh**2** and Zh**3**) including one of the heads (Zh**2**), with the movement of wafer stage WST. However, as well as this method, a modified method of switching to another pair of heads (Zh**3** and Zh**4**) which does not include a common head from a certain pair of heads (for example, Zh**1** and Zh**2**) can be adopted. Also in this modified method, similar to the method described above, the measurement values of the priority head should be used normally, and at the time of abnormality, the measurement values of the auxiliary head should be used representatively as the measurement values of the pair of heads (or the head unit to which these heads belong).

Incidentally, as the cause of abnormality being generated in the measurement values of the Z heads, there is two major causes, that is, a cause coming from malfunction of the head, and a cause coming from abnormality of the reflection surface (in the embodiment, a scale) on which the measurement beam is irradiated. As an example of the former case, a mechanical failure of the head can be representatively given. To be concrete, a failure in the head itself, a failure in the measurement beam light source, a situation where water droplets adhere on the head and the like can be given. A situation where the intensity of the measurement beam becomes extremely low, if not the measurement beam light source fails to operate, can be said to be a cause coming from the head. Meanwhile, as an example of the latter case, the case can be given in which the liquid of the liquid immersion area remains or foreign materials such as dust and the like adheres on the surface of the scale (reflection surface), and the measurement beam scans the remaining liquid or the adhered foreign material.

The method in the embodiment in which a pair of heads configured by a priority head and an auxiliary head is made to constantly face at least one corresponding scale is effective not only to abnormality of the measurement values due to malfunction of the heads, but also effective to abnormality of the measurement values due to abnormality in the scales.

Next, detection of position information (surface position information) of the wafer W surface in the Z-axis direction (hereinafter, referred to as focus mapping) that is performed in exposure apparatus **100** of the embodiment will be described. In the state of FIG. **9**A, a straight line (centerline) parallel to the Y-axis that passes through the center of wafer table WTB (which substantially coincides with the center of wafer W) coincides with reference axis LV previously described.

On this focus mapping, as is shown in FIG. **9**A, main controller **20** controls the position within the XY plane of water table WTB based on the measurement values of one (X linear encoder **70**D) of the two X heads **66** (surrounded by an elongated circle) facing X scale **39**X_2, and a predetermined one (Y linear encoders **70**F_1 and **70**E_1) of the Y heads **68** and **67** (surrounded by elongated circles), which are two heads each, facing Y scales **39**Y_1 and Y_2, respectively. In the state of FIG. **9**A, a straight line (centerline) parallel to the Y-axis that passes through the center of wafer table WTB (which substantially coincides with the center of wafer W) coincides with reference axis LV previously described.

Then, in this state, main controller **20** starts scanning of wafer stage WST in the +Y direction, and after having started the scanning, activates (turns ON) both Z heads **72***a* to **72***d* and the multipoint AF system (**90***a*, **90***b*) by the time when wafer stage WST moves in the +Y direction and detection beams of the multipoint AF system (**90***a*, **90***b*) begin to be irradiated on wafer W.

Then, in a state where Z heads **72***a* to **72***d* and the multipoint AF system (**90***a*, **90***b*) simultaneously operate, as is shown in FIG. **9**B, position information (surface position information) of the wafer table WTB surface (surface of plate **28**) in the Z-axis direction that is measured by Z heads **72***a* to **72***d* and position information (surface position information) of the wafer W surface in the Z-axis direction at a plurality of detection points that is detected by the multipoint AF system (**90***a*, **90***b*) are loaded at a predetermined sampling interval while wafer stage WST is proceeding in the +Y direction, and three kinds of information, which are each surface position information that has been loaded and the measurement values of Y linear encoders **70**F**1** and **70**E**1** at the time of each sampling, are made to correspond to one another and are sequentially stored in a memory (not shown).

Then, when the detection beams of the multipoint AF system (**90***a*, **90***b*) begin to miss wafer W, main controller **20** ends the sampling described above and converts the surface position information at each detection point of the multipoint AF system (**90***a*, **90***b*) into data which uses the surface position information by Z heads **72***a* to **72***d* that has been loaded simultaneously as a reference.

More specifically, based on an average value of the measurement values of Z heads **72***a* and **72***b*, main controller **20** obtains the surface position information of a predetermined point (for example, a point corresponding to a midpoint of the respective measurement points of Z heads **72***a* and **72***b*, that is, a point on substantially the same X-axis as the array of a plurality of detection points of the multipoint AF system (**90***a*, **90***b*): hereinafter, this point is referred to as a left measurement point P1) on an area (an area where Y scale **39**Y_2 is formed) near the edge section on the −X side of plate **28**. Further, based on an average value of the measurement values of Z heads **72***c* and **72***d*, main controller **20** obtains the surface position information at a predetermined point (for example, a point corresponding to a midpoint of the respective measurement points of Z heads **72***c* and **72***d*, that is, a point on substantially the same X-axis as the array of a plurality of detection points of the multipoint AF system (**90***a*, **90***b*): hereinafter, this point is referred to as a right measurement point P**2**) on an area (an area where Y scale **39**Y_1 is formed) near the edge section on the +X side of plate **28**. Then, as shown in FIG. **9**C, main controller **20** converts the surface position information at each detection point of the multipoint AF system (**90***a*, **90***b*) into surface position data z**1**-zk, which uses a straight line that connects the surface position of left measurement point P**1** and the surface position of right measurement point P**2** as a reference. Main controller **20** performs such a conversion on all information taken in during the sampling.

By obtaining such converted data in advance in the manner described above, for example, in the case of exposure, main controller **20** measures the wafer table WTB surface (a point on the area where Y scale **39**Y_2 is formed (a point near left measurement point P**1** described above) and a point on the area where Y scale **39**Y_1 is formed (a point near right measurement point P**1** described above)) with Z heads **74** and **76** previously described, and computes the Z position and θy rotation (rolling) amount θy of wafer table WTB. Then, by performing a predetermined operation using the Z position, the rolling amount θy, and the θx rotation (pitching) amount θx of wafer table WTB measured with Y interferometer **16**, main controller **20** computes the Z position (Z**0**) of the wafer table WTB surface in the center (exposure center) of exposure area IA previously described, or in other words, the Z position (Z**0**) of wafer stage WST, rolling amount θy, and pitching amount θx, and based on the computation results, obtains a straight line passing through the exposure center that connects the surface position of left measurement point P**1** and the surface position of right measurement point P**2** described above, and by using this straight line and surface position data z**1** to zk, performs surface position control (focus leveling control) of the upper surface of wafer W, without actually acquiring the surface position information of the wafer W surface. Accordingly, because there is no problem even if the multipoint AF system is placed at a position away from projection optical system PL, the focus mapping of the embodiment can suitably be applied also to an exposure apparatus and the like that has a short working distance.

Further, in exposure apparatus **100** of the embodiment, a parallel processing operation using wafer stage WST and measurement stage MST, which includes focus mapping and the like described above, is performed, basically in the same procedure as the exposure apparatus disclosed in the embodiment of the pamphlet of International Publication 2007/097379 previously described. Because this parallel processing operation is similar to the exposure apparatus disclosed in the embodiment of the pamphlet of International Publication 2007/097379 previously described except for the following two points, a detailed description will be omitted.

The first point is, when abnormality occurs in the output of one of the priority heads of the surface position measurement system **180** used for measuring positional information of wafer stage WST in the Z direction and the θy direction in the case wafer stage WST is in the range where the stage moves for exposure operation, main controller **20** uses the measurement values of the auxiliary head which configures a pair of heads with the priority head as is previously described as the measurement values of the pair of heads (or the head unit to which the two heads belong) in the Z-axis direction.

The second point is, for example, at the time of stepping operation between shots of wafer stage WST on the exposure operation by the step-and-scan method, a switching of heads is performed by a switching method in which the encoder head used for measuring the positional information of wafer stage WST in the Z-axis direction and the θy direction is switched from a pair of heads (for example, Zh**1** and Zh**2**) to another pair of heads (Zh**2** and Zh**3**) which include one of the heads (Zh**2**).

As discussed in detail above, according to exposure apparatus **100** related to the embodiment, when wafer stage WST is located in the range where wafer stage WST moves for exposure operation by the step-and-scan method, two Z heads each or more of the plurality of Z heads belonging to head units **62**C and **62**A constantly face Y scales **39**Y_1 and **39**Y_2, respectively, arranged on wafer stage WST. Therefore, main controller **20** can constantly measure the positional information of wafer stage WST (wafer table WTB) in the Z-axis direction and rotation information (rolling amount) in the θy direction with high precision (without being affected by air fluctuation and the like), using the measurement results of at least one head (the priority head when the two Z heads are in correspondence with the corresponding Y scales, or the auxiliary head when abnormality occurs in the output of the priority head) of the two Z heads each or more. Further, main controller **20** can measure the θx rotation of wafer table WTB with good accuracy, based on the measurement values of Y interferometer **16**.

Further, according to exposure apparatus **100** related to the embodiment, by performing the focus leveling control of the water with high accuracy during scanning exposure using the Z heads without measuring the surf ace position information of the wafer surface during exposure, based on the results of focus mapping performed beforehand, it becomes possible to form a pattern on wafer W with good precision. Furthermore, in the embodiment, because a high-resolution exposure can be realized by liquid immersion exposure, a fine pattern can be transferred with good precision on wafer W also from this viewpoint.

Further, as is obvious from FIG. **6**, of the plurality of Z heads **74** and **76** respectively belonging to head units **62**C and **62**A used to control the Z position and θy rotation of water table WTB at the time of exposure, the position in the Y-axis direction of a part of the Z heads $\mathbf{74}_6$ to $\mathbf{74}_9$ and $\mathbf{76}_1$ to $\mathbf{76}_4$ is made to be different from other Z heads in the same unit. Accordingly, the plurality of Z heads **74** and **76** belonging to head units **62**C and **62**A can be placed at the empty spaces in the periphery of projection unit PU, while avoiding nozzle unit **32**, liquid supply piping **31**A, and liquid recovery piping **31**B which configure a part of liquid immersion device **8**. The same can be said for the Y heads belonging to head units **62**C and **62**A. In this case, head unit **62**C which includes Z head **74** and Y head **64** and head unit **62**A which includes Z head **76** and Y head **65** can be placed at the empty spaces in the periphery of projection unit PU without any problems, while the distance between adjacent Z heads (and Y heads **64** and **65**) in the X-axis direction is set to a desired distance, as in, for example, distance WD, such as, for example, 35 mm, which is narrower than half the width of Y scales **39**Y_1 and **39**Y_2 in the X-axis direction (for example, 76 mm). Accordingly, the switching between adjacent Z heads can be performed without any problems when wafer table WTB moves, and this also makes it possible to reduce the size of the entire apparatus.

In the embodiment above, while the case has been described where the Z heads belonging to head units **62**A and **62**C are used as a pair of heads with two heads forming a set, along with this, Z heads **72***a*, **72***b*, **72***c*, and **72***d* used at the time of focus mapping can each be configured by a set of two z heads (a pair of heads), and in the pair of heads, one of the heads can be a priority head, and when abnormality occurs in the output of the priority head, the Z head used for Z position control of wafer stage WST can be switched to an auxiliary head.

MODIFIED EXAMPLE

Incidentally, in the embodiment above, two Z heads were constantly facing a common scale (reflection surface) so that the positional information of wafer stage WST in the Z-axis direction can be measured in a stable manner and with high precision. And, of a pair of heads consisting of the two Z heads, measurement values of a priority head was used, and in the case abnormality was generated in the measurement value of the priority head due to malfunction of the head (or abnormality of the scale), measurement values of the other auxiliary head were to be used. However, as well as this, as a measurement method constantly using the two heads, which are the priority head and the auxiliary head, various modified examples can be considered.

Some representative examples will be shown below, which are modified examples, referring to FIGS. **10**A to **12**. Incidentally, in FIGS. **10**A to **12**, scale SY (more specifically, the wafer stage) is to be moved in the—X-direction.

As a first modified example, two Z heads, which are a priority head and a auxiliary head, can be made into a set (to be referred to as a head set), and an example where at least one set is constantly made to face the scale can be given. In this first modified example, as shown in FIG. **10**A, a head set Hs**1** consisting of two Z heads Zh**1** and Zh**2** placed close to the longitudinal direction (the Y-axis direction) of scale SY, and another head set Hs**2** consisting of two Z heads Zh**3** and Zh**4** placed close to the Y-axis direction face one scale, SY. In this first modified example, a plurality of head sets is prepared, configured of two Z heads in proximity to the Y-axis direction, and these head sets are placed in parallel with the X-axis direction at a distance smaller than the effective width of scale SY. Accordingly, one head set will constantly face scale SY.

When scale SY (more specifically, the wafer stage) moves in the –X direction from the state shown in FIG. **10**A, head set Hs**1** moves off of scale SY. To be more precise, irradiation points of measurement beams outgoing from the two heads Zh**1** and Zh**2** constituting head set Hs**1**, or more specifically, measurement points of heads Zh**1** and Zh**2** move off from an effective area of scale SY. Therefore, before head set Hs**1** moves off from scale SY, main controller **20** switches the head set controlling the stage position from head set Hs**1** to head set Hs**2**.

This first modified example is effective not only to abnormality of the measurement values due to malfunction of the heads previously described, but is also effective to abnormality of the measurement values due to abnormality in the scales.

A second modified example following the first modified example described above is shown in FIG. **10**B. As it can be seen when comparing FIGS. **10**B and **10**A, in the first modified example, a configuration was employed where the two Z heads configuring the head set each scanned a different measurement point, whereas in the second modified example, a configuration is employed where the two Z heads configuring the head set scan the same measurement point. Accordingly, in the first modified example, the two Z heads show different measurement values, whereas in the second modified example, the two Z heads normally show measurement values equal to each other By employing the configuration in the second modified example, even if abnormality occurs in the measurement values of a priority head due to mechanical failure and the like in the priority head, which is one of the two heads configuring the head set, the normal measurement values of the other head, or the auxiliary head, can be used as the measurement values of the head set Accordingly, abnormality is not detected in the measurement results as the head set.

Incidentally, the difference in the second modified example and the first modified example is only whether the position of the measurement point of the two Z heads configuring the head set is the same or not. Accordingly, the placement of each head set and the individual z heads configuring each head set in the second modified example should be set in a similar manner as the first modified example. By this arrangement, the procedure of the switching process also becomes the same.

In the first and second modified examples described above, the two Z heads configuring the head set is placed in parallel in the longitudinal direction (Y-axis direction) of the scale. In correspondence with these examples, an example can also be considered where the placement is in parallel in a direction (the X-axis direction) orthogonal to the longitudinal direction of the scale.

FIG. **11**A shows a third modified example, in correspondence with the first modified example in FIG. **10**A. In the third modified example, similar to the first modified example, two heads, which are a priority head and an auxiliary head, are made into a set, and at least one set is constantly made to face the scale. However, in FIG. **11**A, it is different from the first modified example, and a head set Hs**1** consisting of two heads Zh**1** and Zh**2** placed close to the effective width direction (the X-axis direction) of scale SY, and another head set Hs**2** consisting of two heads Zh**3** and Zh**4** placed close to the X-axis direction face one scale, SY. In this third modified example, a plurality of head sets is prepared, configured of two Z heads in proximity to the X-axis direction, and these head sets are placed in parallel with the X-axis direction so that one head set constantly faces scale SY.

When scale SY (more specifically, the wafer stage) moves in the −X direction from a state shown in FIG. **11**A, the measurement point of Z head Zh**1** moves off from the effective area of scale SY. If, supposing that Z head Zh**1** was chosen as the priority head of head set Hs**1**, the main controller **20** switches the priority head to Z head Zh**2** at a point in time when Z head Zh**1** moves off from scale SY. Furthermore, when scale SY moves in the −X direction, then the measurement point of head Zh**2** moves off from scale SY. Therefore, by this point in time at the latest, or more specifically, before the measurement point of both heads Zh**1** and Zh**2** configuring head set Hs**1** moves off from scale SY, the head set controlling the stage position is switched from bead set Hs**1** to head set Hs**2**.

This third modified example, similar to the first modified example, is effective not only to abnormality of the measurement values due to malfunction of the heads previously described, but is also effective to abnormality of the measurement values due to abnormality in the scales.

A fourth modified example following the third modified example described above is shown in FIG. **11**B. As it can be seen when comparing FIGS. **11**B and **11**A, in the third modified example, a configuration was employed where the two Z heads configuring the head set each scanned a different measurement point, whereas in the fourth modified example, a configuration is employed where the same measurement point is scanned. Accordingly, in the third modified example, the two Z heads show different measurement values, whereas in the fourth modified example, the two Z heads normally show measurement values equal to each other. By the configuration in the fourth modified example, even if abnormality occurs in the measurement values of a priority head of the two Z heads configuring the head set due to mechanical failure and the like in the priority head, the normal measurement values of the other head, or the auxiliary head, can be used, therefore, abnormality is not detected in the measurement results as the head set.

Incidentally, the difference in the fourth modified example and the third modified example is only whether the position of the measurement point of the two Z heads configuring the head set is the same or not Accordingly, the placement of each head set and the individual Z heads configuring each head set in the fourth modified example should be set in a similar manner as the third modified example. By this arrangement, the procedure of the switching process also becomes the same.

Further, as is obvious when comparing FIGS. **11**B and **10**B, since the fourth modified example and the second modified example are different merely regarding the proximity direction of the two Z heads which configure the head set, the effect that can be obtained is the same.

Further, in the third modified example in FIG. **11**A, the distance of two adjacent head sets, was set to a distance so that the irradiation points (measurement points) of the measurement beams outgoing from (all four heads configuring) the two head sets were located within the effective area of scale SY. However, by reason of the switching process of the headset, the placement distance of the two adjacent headsets can be set to a placement distance in which the two Z heads (Zh**3**, Zh**4**) configuring one head set (Hs**2**) and one of the Z heads (Zh**2**) of the two heads (Zh**1**, Zh**2**) configuring the other head set (Hs**1**), or three Z heads (Zh**2**, Zh**3**, and Zh**4**), face scale SY, as shown in FIG. **12**.

Incidentally, in the tour modified examples, while a head set consisting of one priority head and one auxiliary head was used, the number of auxiliary heads is not limited to one, and a plurality of auxiliary heads can be arranged. In the case of using an encoder head having such a configuration, reliability of the measurement results improves because more measurement data can be detected. Further, in the case the plurality of heads within the head set are observed to be at the same position in the transverse direction (the X-axis direction in the modified examples) of the scale as in the four modified examples, priority cannot be given according to the guidelines such as, "priority given to the head which becomes effective first," or "priority given to the head closer to the scale center." Accordingly, it is desirable to decide a fixed priority order in the headset in advance.

Incidentally, the configuration of each measurement device such as the surface position measurement system described in the embodiment above is only an example, and it is a matter of course that the present invention is not limited to this. For example, in the embodiment above, while an example has been described where a surface position measurement system was employed that has a configuration of having a reflection surface (Y scale) arranged on the wafer table (wafer stage) and a Z head placed facing the reflection surface external to the wafer stage, a surface position measurement system having a configuration of a Z head being arranged on the wafer stage and a reflection surface arranged external to the wafer stage facing the Z head can also be employed. In this case, at least two encoder heads can be arranged on a plurality of places on the wafer stage, for example, on the four corners, and with one of the at least two encoder heads serving as a priority head and the remaining at least one encoder head serving as an auxiliary head, position control of the wafer stage can be performed similarly as in the embodiment and the modified examples above. Incidentally, the at least two encoder heads can be placed in proximity on the wafer stage, or can be placed a predetermined distance apart. Especially in the latter case, the heads can be placed along a radiation direction from the center of the wafer stage.

Further, because the surface of the reflection surface arranged external to the wafer stage faces downward, the liquid of the liquid immersion area will not remain and foreign materials such as dust and the like will not adhere on the surface. Accordingly, because abnormality of the Z head output due to the abnormality of the reflection surface does not have to be considered, the controller which performs the switching of the heads can decide to monitor only the output abnormality of the priority head due to the malfunction of the head.

Further, in the embodiment and the modified examples above, while the case has been described where the encoder head and the Z head were separately arranged, every encoder head can have a Z head, or each encoder head can be equipped with a Z head, or each encoder head can be a head (sensor) that can perform position detection in two directions, which are the X-axis or Y-axis direction, and the Z-axis direction Especially in the former case, the encoder head and the Z head can be integrally arranged.

Further, in the embodiment and the modified examples above, malfunction (abnormality) of the encoder head includes gradient of the head or loss of telecentricity, besides mechanical failure. Further, in the case of the type of encoder system which has a head arranged on the stage and a scale arranged above the head, the case when foreign materials (including, for example, the liquid for liquid immersion) adhere on the head is included in the abnormality (malfunction) of the encoder head. Further, not only in the case when the position becomes unmeasurable, but the case when the measurement accuracy exceeds a permissible value (the output (intensity) of the encoder head results to be outside the permissible range) is also included in the abnormality of the encoder head.

Further, in the embodiment above, while the case has been described where head units **62**A and **62**C each are equipped with nine Z heads, the number is not an issue as long as there are two or more Z heads which can simultaneously face a pair of reflection surfaces (in the embodiment above, Y scales **39**Y_1 and **39**Y_2) arranged on both sides of projection units.

Further, because rotation information in the θy direction of wafer table WTB (wafer stage WST) can also be measured using Z interferometers **43**A and **43**B, or X interferometer **126**, the Z head can be arranged in a plurality of numbers on either one of head units **62**A or **62**C. From a similar point, if the Y scale which is the measurement object of the 2 head is used only for the purpose of measuring the Z position of wafer table WTB, only one of Y scales **39**Y_1 and **39**Y_2 arranged is enough. Further, as the measurement object of the Z head, instead of Y scales **39**Y_1 and **39**Y_2, an exclusive reflection surface can be formed on the upper surface of wafer table WTB.

Further, in the embodiment above, while the case has been described where Z heads **74** and **76** were placed avoiding nozzle unit **32** and the like configuring a part of the liquid immersion system, in the case a plurality of sensor heads are arranged in a straight line parallel to the X-axis, it is desirable to at least move some sensor heads from the straight line in order to avoid the structures that are located on the straight line. As such a structure, besides projection optical unit PU and its peripheral members, at least a part of multipoint AF system (**90**_a_, **90**_b_), or at least a part of alignment systems AL**1** and AL**2**$_n$ can be representatively given. In the embodiment above, Z heads **72**_a_ to **72**_d_ are placed, avoiding multipoint AF system (**90**_a_, **90**_b_).

Incidentally, in the embodiment above, while the lower surface of nozzle unit **32** and the lower end surface of the tip optical element of projection optical system PL were substantially flush, as well as this, for example, the lower surface of nozzle unit **32** can be placed nearer to the image plane (more specifically, to the wafer) of projection optical system PL than the outgoing surface of the tip optical element. That is, the configuration of local liquid immersion device **8** is not limited to the configuration described above, and the configurations which are described in, for example, EP Patent Application Publication No. 1420298, U.S. patent Application Publication 2006/0231206, U.S. patent Application Publication 2005/0280791, and U.S. Pat. No. 6,952,253 and the like can also be used. Further, as disclosed in, for example, U.S. patent Application Publication No. 2005/0248856, the optical path on the object plane side of the tip optical element can also be filled with liquid, in addition to the optical path on the image plane side of the tip optical element. Furthermore, a thin film that is lyophilic and/or has dissolution preventing function may also be formed on the partial surface (including at least a contact surface with liquid) or the entire surface of the tip optical element. Incidentally, quartz has a high affinity for liquid, and also needs no dissolution preventing film, while in the case of fluorite, at least a dissolution preventing film is preferably formed.

Incidentally, in the embodiment above, pure water (water) was used as the liquid, however, it is a matter of course that the present invention is not limited to this. As the liquid, a chemically stable liquid that has high transmittance to illumination light IL and is safe to use, such as a fluorine-containing inert liquid can be used. As the fluorine-containing inert liquid, for example, Fluorinert (the brand name of 3M United States) can be used. The fluorine-containing inert liquid is also excellent from the point of cooling effect. Further, as the liquid, liquid which has a refractive index higher than pure water (a refractive index is around 1.44), for example, liquid having a refractive index equal to or higher than 1.5 can be used. As this type of liquid, for example, a predetermined liquid having C-H binding or O—H binding such as isopropanol having a refractive index of about 1.50, glycerol (glycerin) having a refractive index of about 1.61, a predetermined liquid (organic solvent) such as hexane, heptane or decane, or decalin (decahydronaphthalene) having a refractive index of about 1.60, or the like can be cited. Alternatively, a liquid obtained by mixing arbitrary two or more of these liquids may be used, or a liquid obtained by adding (mixing) at least one of these liquids to (with) pure water may be used. Alternatively, as the liquid, a liquid obtained by adding (mixing) base or acid such as H^+, Cs^+, K^+, Cl^-, SO_4^{2-}, or PO_4^{2-} to (with) pure water can be used. Moreover, a liquid obtained by adding (mixing) particles of Al oxide or the like to (with) pure water can be used. These liquids can transmit ArF excimer laser light. Further, as the liquid, liquid, which has a small absorption coefficient of light, is less temperature-dependent, and is stable to a projection optical system (tip optical member) and/or a photosensitive agent (or a protection film (top coat film), an antireflection film, or the like) coated on the surface of a wafer, is preferable. Further, in the case an F_2 laser is used as the light source, fomblin oil can be selected. Further, as the liquid, a liquid having a higher refractive index to illumination light IL than that of pure water, for example, a refractive index of around 1.6 to 1.0 may be used. As the liquid, supercritical fluid can also be used. Further, the tip optical element of projection optical system PL may be formed by quartz (silica), or single-crystal materials of fluoride compound such as calcium fluoride (fluorite), barium fluoride, strontium fluoride, lithium fluoride, and sodium fluoride, or may be formed by materials having a higher refractive index than that of quartz or fluorite (e.g. equal to or higher than 1.6). As the materials having a refractive index equal to or higher than 1.6, for example, sapphire, germanium dioxide, or the like disclosed in the pamphlet of International Publication No. 2005/059617, or kalium chloride (having a refractive index of about 1.75) or the like disclosed in the pamphlet of International Publication No. 2005/059618 can be used.

Further, in the embodiment above, the recovered liquid may be reused, and in this case, a filter that removes impurities from the recovered liquid is preferably arranged in a liquid recovery unit, a recovery pipe or the like.

Further, in the embodiment above, the case has been described where the exposure apparatus is a liquid immersion type exposure apparatus. However, the present invention is not limited to this, but can also be employed in a dry type exposure apparatus that performs exposure of wafer W without liquid (water).

Further, in the embodiment above, the case has been described where the present invention is applied to a scanning exposure apparatus by a step-and-scan method or the like. However, the present invention is not limited to this, but may also be applied to a static exposure apparatus such as a stepper. Even in the case of a stepper, because the Z position of the wafer table on which the object subject to exposure is mounted can be measured using a Z head as in the embodiment described above, a similar effect can be obtained. Further, the present invention can also be applied to a reduction projection exposure apparatus by a step-and-stitch method that synthesizes a shot area and a shot area, an exposure apparatus by a proximity method, a mirror projection aligner, or the like. Moreover, the present invention can also be applied to a multi-stage type exposure apparatus equipped with a plurality of wafer stages, as is disclosed in, for example, the U.S. Pat. Nos. 6,590,634, 5,969,441, 6,208,407 and the like.

Further, the magnification of the projection optical system in the exposure apparatus of the embodiment above is not only a reduction system, but also may be either an equal magnifying system or a magnifying system, and projection optical system PL is not only a dioptric system, but also may be either a catoptric system or a catodioptric system, and in addition, the projected image may be either an inverted image or an upright image. Further, the illumination area and exposure area described above are to have a rectangular shape. However, the shape is not limited to rectangular, and can also be circular arc, trapezoidal, parallelogram or the like.

Incidentally, a light source of the exposure apparatus in the embodiment above is not limited to the ArF excimer laser, but a pulse laser light source such as a KrF excimer laser (output wavelength: 248 nm), an F_2 laser (output wavelength: 157 nm), an Ar_2 laser (output wavelength: 126 nm) or a Kr2 laser (output wavelength: 146 nm), or an extra-high pressure mercury lamp that generates an emission line such as a g-line (wavelength: 436 nm), an i-line (wavelength: 365 nm) and the like can also be used. Further, a harmonic wave generating unit of a YAG laser or the like can also be used. Besides the sources above, as is disclosed in, for example, U.S. Pat. No. 7,023,610, a harmonic wave, which is obtained by amplifying a single-wavelength laser beam in the infrared or visible range emitted by a DFB semiconductor laser or fiber laser as vacuum ultraviolet light, with a fiber amplifier doped with, for example, erbium (or both erbium and ytteribium), and by converting the wavelength into ultraviolet light using a non-linear optical crystal, can also be used.

Further, in the embodiment above, illumination light TL of the exposure apparatus is not limited to the light having a wavelength equal to or more than 100 nm, and it is needless to say that the light having a wavelength less than 100 nm can be used. For example, in recent years, in order to expose a pattern equal to or less than 70 nm, an EUV exposure apparatus that makes an SOR or a plasma laser as a light source generate an EUV (Extreme Ultraviolet) light in a soft X-ray range (e.g. a wavelength range from 5 to 15 nm), and uses a total reflection reduction optical system designed under the exposure wavelength (for example, 13.5 nm) and the reflective mask has been developed. In the EUV exposure apparatus, the arrangement in which scanning exposure is performed by synchronously scanning a mask and a wafer using a circular arc illumination can be considered, and therefore, the present invention can also be suitably applied to such an exposure apparatus. Besides such an apparatus, the present invention can also be applied to an exposure apparatus that uses charged particle beams such as an electron beam or an ion beam.

Further, in the embodiment above, a transmissive type mask (reticle) is used, which is a transmissive substrate on which a predetermined light shielding pattern (or a phase pattern or a light attenuation pattern) is formed. Instead of this reticle, however, as is disclosed in, for example, U.S. Pat. No. 6,778,257, an electron mask (which is also called a variable shaped mask, an active mask or an image generator, and includes, for example, a DMD (Digital Micromirror Device) that is a type of a non-emission type image display device (spatial light modulator) or the like) on which a light-transmitting pattern, a reflection pattern, or an emission pattern is formed according to electronic data of the pattern that is to be exposed can also be used.

Further, for example, the present invention can also be applied to an exposure apparatus (lithography system) that forms line-and-space patterns on a wafer by forming interference fringes on the wafer.

Moreover, as disclosed in, for example, U.S. Pat. No. 6,611,316, the present invention can also be applied to an exposure apparatus that synthesizes two reticle patterns via a projection optical system and almost simultaneously performs double exposure of one shot area by one scanning exposure.

Further, an apparatus that forms a pattern on an object is not limited to the exposure apparatus (lithography system) described above, and for example, the present invention can also be applied to an apparatus that forms a pattern on an object by an ink-jet method.

Incidentally, an object on which a pattern is to be formed (an object subject to exposure to which an energy beam is irradiated) in the embodiment above is not limited to a wafer, but may be other objects such as a glass plate, a ceramic substrate, a film member, or a mask blank.

The use of the exposure apparatus is not limited only to the exposure apparatus for manufacturing semiconductor devices, but the present invention can also be widely applied, for example, to an exposure apparatus for transferring a liquid crystal display device pattern onto a rectangular glass plate, and an exposure apparatus for producing organic ELs, thin-film magnetic heads, imaging devices (such as CCDs), micromachines, DNA chips, and the like. Further, the present invention can be applied not only to an exposure apparatus for producing microdevices such as semiconductor devices, but can also be applied to an exposure apparatus that transfers a circuit pattern onto a glass plate or silicon wafer to produce a mask or reticle used in a light exposure apparatus, an EUV exposure apparatus, an X-ray exposure apparatus, an electron-beam exposure apparatus, and the like.

Incidentally, the disclosures of the various publications, the pamphlets of the International Publications, and the U.S.

patent Application Publication descriptions and the U.S. patent descriptions that are cited in the embodiment above and related to exposure apparatuses and the like are each incorporated herein by reference.

Electronic devices such as semiconductor devices are manufactured through the steps of; a step where the function/performance design of the device is performed, a step where a reticle based on the design step is manufactured, a step where a wafer is manufactured from silicon materials, a lithography step where the pattern of a reticle is transferred onto the wafer by the exposure apparatus (pattern formation apparatus) in the embodiment previously described, a development step where the wafer that has been exposed is developed, an etching step where an exposed member of an area other than the area where the resist remains is removed by etching, a resist removing step where the resist that is no longer necessary when etching has been completed is removed, a device assembly step (including a dicing process, a bonding process, the package process), inspection steps and the like. In this case, in the lithography step, because the device pattern is formed on the wafer by executing the exposure method previously described using the exposure apparatus of the embodiment, a highly integrated device can be produced with good productivity.

While the above-described embodiments of the present invention are the presently preferred embodiments thereof, those skilled in the art of lithography systems will readily recognize that numerous additions, modifications, and substitutions may be made to the above-described embodiments without departing from the spirit and scope thereof. It is intended that all such modifications, additions, and substitutions fall within the scope of the present invention, which is best defined by the claims appended below.

What is claim is:

1. A movable body apparatus including a movable body which substantially moves along a predetermined plane, the apparatus comprising:

a reflection surface which is arranged at one of the movable body and the outside of the movable body, with a first direction within a plane parallel to the predetermined plane serving as a longitudinal direction, and having a predetermined width in a second direction orthogonal to the first direction;

a measurement device which has a plurality of sensors, each of the plurality of sensors measuring positional information of the movable body in a third direction orthogonal to the predetermined plane at a plurality of measurement points placed on the reflection surface; and

a controller which performs position control of the movable body,

wherein:

the placement of the plurality of measurement points is decided so that of the plurality of measurement points, n points (wherein, n is an integer of two or more) or more are positioned within the predetermined width on the reflection surface, and when the movable body is at a predetermined position, n+1 or more of the plurality of measurement points are positioned to be within the predetermined width on the reflection surface, and

the controller performs the position control of the movable body, using first measurement information that includes measurement information at a first measurement point out of the n points or more measurement points positioned within the predetermined width on the reflection surface or the n+1 or more measurement points positioned within the predetermined width on the reflection surface when the movable body is at the predetermined position, and switches measurement information used for the position control of the movable body to second measurement information that includes measurement information at a second measurement point which is different from the first measurement point, in the case where abnormality occurs in the first measurement information due to malfunction of at least one of the plurality of sensors when the movable body is at a position where the measurement at the first measurement point is performed.

2. The movable body apparatus according to claim **1** wherein

the reflection surface is arranged on a surface substantially parallel to the predetermined plane of the movable body.

3. The movable body apparatus according to claim **2** wherein

in the movable body, the reflection surface is arranged apart in a pair in the second direction, and

the placement of the measurement points is decided so that the n or more measurement points are constantly positioned in at least one of the pair of reflection surfaces when the movable body is in a predetermined range within the predetermined plane.

4. The movable body apparatus according to claim **1** wherein

each of the first measurement information and the second measurement information includes measurement information at a plurality of measurement points.

5. The movable body apparatus according to claim **1** wherein

each of the first measurement information and the second measurement information is measurement information at one measurement point.

6. The movable body apparatus according to claim **1** wherein

the measurement device has a plurality of heads which irradiate measurement beams on the measurement point, and

the controller performs the switching when the abnormality in the measurement information occurs due to malfunction of the heads.

7. The movable body apparatus according to claim **1** wherein

the measurement device has a plurality of heads which irradiate measurement beams on a measurement point, and the plurality of heads irradiate the measurement beams on different measurement points, respectively.

8. The movable body apparatus according to claim **1** wherein

the measurement points are placed in the second direction, each spaced apart by half or less than half the predetermined width of the reflection surface at a substantially equal distance.

9. The movable body apparatus according to claim **1** wherein

the measurement device has a first and second head which irradiate measurement beams on a same measurement point, and

an irradiation area of the measurement beam irradiated from the first head is in proximity with an irradiation area of the measurement beam irradiated by the second head, without overlapping.

10. A pattern formation apparatus that forms a pattern on an object, the apparatus comprising:

a patterning device which forms the pattern on the object, and the movable body apparatus according to claim **1** in which the object is mounted on the movable body.

11. The pattern formation apparatus according to claim **10** wherein

the object has a sensitive layer, and the patterning device forms the pattern on the object by exposing the sensitive layer.

12. An exposure apparatus that forms a pattern on an object by irradiating an energy beam, the apparatus comprising:

a patterning device that irradiates the energy beam on the object;

the movable body apparatus according to claim **1** in which the object is mounted on the movable body, and

a driver which drives the movable body to make the object relatively move with respect to the energy beam.

13. A device manufacturing method comprising:

exposing an object using the exposure apparatus according to claim **12**; and

developing the object that has been exposed.

14. A movable body apparatus including a movable body which substantially moves along a predetermined plane, the apparatus comprising:

a reflection surface which is arranged at one of the movable body and the outside of the movable body, with a first direction within a plane parallel to the predetermined plane serving as a longitudinal direction, and which has a predetermined width in a second direction orthogonal to the first direction;

a measurement device which measures positional information of the reflection surface in a third direction orthogonal to the predetermined plane at a plurality of measurement points placed on the reflection surface, the measurement device having a plurality of head sets each of which includes a first head that irradiates a measurement beam on a first measurement point and a second head that irradiates a measurement beam on the first measurement point concurrently with the first head; and

a controller which controls a position of the movable body using measurement information generated by the first head, and also switches the measurement information used from the measurement information generated by the first head to measurement information generated by the second head in the case where abnormality occurs in the measurement information generated by the first head, wherein

the controller performs the switching when the abnormality in the measurement information occurs due to malfunction of at least one of the first head and the second head.

15. The movable body apparatus according to claim **14** wherein

the reflection surface is arranged on a surface substantially parallel to the predetermined plane of the movable body.

16. The movable body apparatus according to claim **14** wherein

measurement points, on which the measurement beams are irradiated by the first head and the second head included in the head sets, are placed, each by the predetermined width, at a substantially equal distance.

17. The movable body apparatus according to claim **14** wherein

in the measurement device, at least a part of a measurement area where the measurement beam of the first head irradiates overlaps at least a part of a measurement area where the measurement beam of the second head irradiates.

18. A pattern formation apparatus that forms a pattern on an object, the apparatus comprising:

a patterning device which forms the pattern on the object, and

the movable body apparatus according to claim **14** in which the object is mounted on the movable body.

19. The pattern formation apparatus according to claim **18** wherein

the object has a sensitive layer, and the patterning device forms the pattern on the object by exposing the sensitive layer.

20. An exposure apparatus that forms a pattern on an object by irradiating an energy beam, the apparatus comprising:

a patterning device that irradiates the energy beam on the object;

the movable body apparatus according to claim **14** in which the object is mounted on the movable body; and

a driver which drives the movable body to make the object relatively move with respect to the energy beam.

21. A device manufacturing method comprising:

exposing an object using the exposure apparatus according to claim **20**; and

developing the object that has been exposed.

22. A movable body apparatus including a movable body which substantially moves along a predetermined plane including a first direction and a second direction orthogonal to the first direction, the apparatus comprising:

a measurement device which measures positional information of the movable body in a direction orthogonal to the predetermined plane, at a plurality of measurement points placed in a movement range of the movable body, whereby

the measurement device has a plurality of heads disposed along the first direction and along the second direction, each of the plurality of heads concurrently generating measurement information regarding a same measurement point when the movable body is located at a predetermined position.

23. The movable body apparatus according to claim **22** wherein

the head is placed at the movable body.

24. The movable body apparatus according to claim **22** wherein

the movable body has a reflection surface which reflects measurement beams irradiated from the heads.

25. The movable body apparatus according to claim **22** wherein

the plurality of heads includes a first head and a second head which irradiate measurement beams on the same measurement point of the plurality of measurement points when the movable body is at the predetermined position, and

at the measurement point, at least a part of an irradiation area of the measurement beam irradiated from the first head overlaps at least a part of an irradiation area of the measurement beam irradiated from the second head.

26. The movable body apparatus according to claim **22** wherein

the plurality of heads includes a first head and a second head which irradiate measurement beams on the same measurement point of the plurality of measurement points when the movable body is at the predetermined position, and

at the measurement point, an irradiation area of the measurement beam irradiated from the first head is in proximity with an irradiation area of the measurement beam irradiated from the second head, without overlapping.

27. The movable body apparatus according to claim 22 wherein

the plurality of heads includes a first head and a second head which irradiate measurement beams on the same measurement point of the plurality of measurement points when the movable body is at the predetermined position, and the apparatus further comprises:

a controller which controls a position of the movable body using measurement information generated by the first head of the plurality of heads irradiating measurement beams on the same measurement point, and also switches the measurement information used from the measurement information generated by the first head to measurement information generated by the second head of the plurality of heads in the case where abnormality occurs in the measurement information generated by the first head.

28. The movable body apparatus according to claim 27 wherein

the controller performs the switching when the abnormality in the measurement information occurs due to malfunction of the heads.

29. A pattern formation apparatus that forms a pattern on an object, the apparatus comprising:

a patterning device which forms the pattern on the object, and

the movable body apparatus according to claim 22 in which the object is mounted on the movable body.

30. The pattern formation apparatus according to claim 29 wherein

the object has a sensitive layer, and the patterning device forms the pattern on the object by exposing the sensitive layer.

31. An exposure apparatus that forms a pattern on an object by irradiating an energy beam, the apparatus comprising:

a patterning device that irradiates the energy beam on the object;

the movable body apparatus according to claim 22 in which the object is mounted on the movable body, and

a driver which drives the movable body to make the object relatively move with respect to the energy beam.

32. A device manufacturing method comprising:

exposing an object using the exposure apparatus according to claim 31; and

developing the object that has been exposed.

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